Type B Accident Investigation of the Americium Contamination Accident at the Sigma Facility, Los Alamos National Laboratory, New Mexico July 14, 2005

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On August 15, 2005, I appointed a Type B Accident Investigation Board to investigate the July 14, 2005 Americium-241 contamination accident at the Sigma Facility of Los Alamos National Laboratory, in Los Alamos, New Mexico. The Board's responsibilities have been completed with respect to this investigation. The analysis, identification of contributing and root causes, and judgments of need reached during the investigation were performed in accordance with DOE Order 225.1A, Accident Investigations.

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

Edwin L. Wilmot
Manager, Los Alamos Site Office
National Nuclear Security Administration

12/01/05
Date

This report is an independent product of the Type B Accident Investigation Board appointed by Edwin L. Wilmot, Manager of the Los Alamos Site Office of the National Nuclear Security Administration, U.S. Department of Energy.

The Board was appointed to perform a Type B investigation of this accident and to prepare an investigation report in accordance with DOE Order 225.1A, Accident Investigations.

The discussion of facts, as determined by the Board, 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.

Prologue
Interpretation of Significance

On July 14, 2005, a worker at the Los Alamos National Laboratory received and opened a shipment of radioactive material from another facility in the Laboratory. The material had been inadvertently contaminated during its preparation in a glovebox. The material was not evaluated for radiological contamination before being shipped, even though it was known that there was a good possibility for contamination. The shippers assumed that the receiver knew there was a potential for contamination and would act accordingly. The receiver assumed that the material was not contaminated because he had not been told otherwise.

The contamination was not discovered for eleven days. In the interim, the contaminant was spread through the receiving facility, the worker's home, two of his relatives' homes, and the homes or vehicles of two other workers. An extensive effort, with activities in four states, was necessary to respond to this accident. However, the situation could have been much worse, given the amount of dispersible contaminant actually involved. It was only the reactive chemical properties of the contaminant when it was exposed to air that limited its spread.

This accident occurred due to a collection of accepted practices, implied assumptions, and assumed requirements that had developed in both facilities long before the onset of the events leading to this accident. Those latent causal factors resulted in circumventions of institutional controls established to avoid such an accident. The workers had developed a level of knowledge, confidence, and comfort in their work environment that led them to become complacent. The communications and decisions at both facilities were based on assumptions that were never stated or verified. The facilities' implementation of institutional requirements did not always address the requirements' intent, and sometimes conflicted with the requirements.

This accident could have been prevented. There was ample evidence available so that feedback and improvement processes could have detected and corrected the latent causal factors. The Laboratory's processes had not developed to a level adequate to provide effective monitoring of the workplaces. The NNSA oversight processes had depended on the Laboratory's feedback and improvement processes without verifying their adequacy, and the NNSA oversight processes themselves had not been adequately established and monitored.

The occurrence of this accident demonstrates the important contribution that an effective feedback and improvement program can make to help workers remain safe. Extensive effort is placed on giving workers the training and experience necessary to become confident in performing the work expected of them. However, complacency develops naturally as the level of confidence increases, and the workers will not recognize its influence on their work habits and behaviors. An explicit overview of the workplace, designed to monitor work practices against established expectations, is necessary to help the workers maintain the level of knowledge and confidence necessary to work safely, without the loss of vigilance that complacency represents.

Douglas M. Minnema

Douglas M. Minnema, Chairperson
DOE Accident Investigation Board
National Nuclear Security Administration

Executive Summary

Overview

On July 14, 2005, a worker at the Sigma Facility of Los Alamos National Laboratory (LANL) received a shipment of 18 uranium nitride pellets from LANL's Plutonium Facility (PF-4). The pellets had been produced in a glovebox line in PF-4 that was also used to produce pellets for a different research program that were a mixture of plutonium and americium (referred to as 'actinide pellets'). The Sigma worker's task was to weld the pellets into specially designed individual cans so that the pellets could undergo test irradiations in a reactor. The welding work was to be done with a laser-welder enclosed in a glovebox designed to maintain an inert atmosphere for the welding process. The 18 uranium nitride pellets were contained in 9 Swagelok® couplings sealed with end caps to maintain an inert atmosphere on the pellets during the transfer between the facilities.

The Sigma worker assumed that the components were not contaminated except for the possibility of low levels of uranium. In contrast, the PF-4 staff that had produced the pellets and loaded the Swageloks® knew that there was a good probability for contamination on the Swageloks®, and that there was no intention to decontaminate the parts after removal from the PF-4 gloveboxes. Regardless, they did not attempt to evaluate the contamination levels on the Swageloks®, nor did they explicitly inform the Sigma worker of the potential for contamination. They knew that the parts were to be placed in the glovebox at Sigma and they assumed that the worker was prepared to accept the parts with contamination. Therefore, neither party was aware that the Swageloks® had inadvertently become highly contaminated with americium-241 from an unrelated activity performed in the same glovebox and adjacent to where the Swageloks® were loaded.

After accepting the shipment, the Sigma worker took it to the laser-welding glovebox. He opened the outer drum and placed the inner container with the Swageloks® into the glovebox to maintain the inert atmosphere on the parts. When he opened the inner container, he found that the parts had been sealed inside multiple plastic bags, so he passed his knife into the glovebox and sliced open the plastic bags. He then removed the plastic bags and knife from the glovebox and placed the knife in its sheath on his belt and the plastic bags on a nearby table. The worker then confirmed the serial numbers on the Swageloks®, gave a piece of paper with those numbers to the nuclear materials custodian for the records, and left the facility for a three day weekend. Since the room was not in an established radiological control area, there was no personnel contamination monitoring necessary in order to leave the facility.

On that day the worker's spouse, currently working in Colorado, drove to Los Alamos to meet him The next morning they drove together to Kansas to visit a relative for the weekend. The following week, the worker's spouse returned to Colorado, and the worker returned to Sigma and continued to work in the laser-welding glovebox, although not with the Swageloks®. He also worked in other areas of Sigma and attended meetings at other LANL locations. Unknown to him, he was contaminated both during the initial work and during work of the following week, and was tracking the contamination to the various locations that he visited. Also, he handled and contaminated some non-radioactive weld coupons that were then shipped to Bettis Atomic Power Laboratory, in Pennsylvania, that week.

On July 25, the Sigma radiological control technician supervisor was in the room containing the laser-welding glovebox, and discovered that the worker had opened the shipment. She conducted a limited radiological survey to check for contamination. The results indicated high levels of contamination of a nature that was not expected in Sigma; she expanded the surveys, assigned a technician to survey the worker, submitted samples for more extensive evaluation, and made notifications to appropriate management. As the surveys began to discover contamination in other areas and on the worker, the scope of the response expanded rapidly. During the afternoon of July 25, a DOE Radiological Assistance Program team was deployed to the worker's residence and verified the presence of americium-241 contamination there.

The following morning the Deputy Laboratory Director established an ad hoc management team to take charge of the onsite and offsite response activities. The management team was divided into two groups in order to separately manage the onsite and offsite responses, but the two groups maintained close communications to share information. The ad hoc management team continued operations for at least two weeks before standing down.

Once the operations were returned to normal operating status, the Los Alamos Site Office Manager appointed this Type B Accident Investigation Board (the Board) to evaluate both the accident and the response activities in order to collect lessons learned and recommend actions necessary to reduce the probability of such an accident in the future and to improve the mitigation and response processes. The Board began onsite activities on August 16 and completed the onsite portion of the investigation on October 18.

Analysis

The production of the pellets was conducted in campaigns, and between campaigns the glovebox line was 'housecleaned' to minimize the probability of cross-contamination of the products. The Board determined that the loading of the Swageloks® had actually been done after a new campaign of actinide pellets had started. The glovebox where the Swageloks® were loaded also contained a furnace for baking the pellets, and the PF-4 staff indicated that 20-30% of the americium in the pellets would volatilize during the furnace runs. Records indicated that two of these furnace runs had been conducted after the housecleaning activity but before the Swageloks® were loaded. The workspace where the Swageloks® were loaded is in the direct path of any dust that would be swept out during loading and unloading the furnace. By evaluating contamination samples taken in the glovebox after the discovery of the contamination at Sigma, the Board was able to demonstrate a direct correlation between the contamination levels in the glovebox and the contamination levels found on the Swageloks® when the Board had them surveyed at Sigma.

In reviewing the project planning and the interactions between the PF-4 and the Sigma staff, the Board determined that multiple meetings and frequent communications had occurred between the two groups. Other than ensuring that the work with the uranium was within the envelope of Sigma's approved facility safety plan, there were no explicit discussions of the safety aspects of the work. The potential for contamination on the Swageloks® was never explicitly addressed by either group. In preparing the package for shipment to Sigma, the PF-4 staff did not characterize the levels of contamination on the Swageloks®. In reviewing the shipping papers, the Board determined that there was no other information on the documents that conveyed the possibility of contamination to the receiving party. When the shipment arrived at Sigma, the radiological control staff was not notified. Consequently, a receipt inspection was not conducted. The radiological control staff was not aware of the planned activity until the week after the package was opened, and at that time the discussion only concerned the welding work.

Outside of designated radiological work areas, the Sigma building is not controlled for radiological purposes. The room with the laser-welding glovebox was not within any of those areas. Sigma can accommodate short-term work with radioactive material in this room, but those controls had not been put in place yet. The radiation protection program at Sigma was designed on the assumption that the work only involved depleted uranium or small quantities of enriched uranium. Therefore, all instrumentation was selected for uranium monitoring, and the routine surveillance practices were designed to monitor the designated uranium work areas. The Board determined that Sigma was actually authorized to accept any radioactive material, as long as the total inventory of the facility remained below the DOE thresholds for a category-3 nuclear facility. The quantity of americium introduced in this event was less than 1% of the corresponding threshold value, and would not have significantly impacted the aggregate total.

In the course of this investigation, the Board encountered a significant number of procedural non-adherences, unverified assumptions, and undocumented requirements. The Board defined the following terms: ***accepted practices*** are practices that have developed and become engrained in the workers even though they are contrary to procedures, policies, and established requirements; ***implied assumptions*** are assumptions that have not been clearly defined or stated, and therefore have never been evaluated or verified; and ***assumed requirements*** are requirements that are believed to be in place, but in reality are either not documented or are misinterpretations of the actual requirements. The Board determined that most of the causal factors for this accident fit into these categories, that these conditions were significant influences in the behavior of the workers, and that all of the accident's causal factors were well established, or latent, in the facilities prior to the onset of the events leading to this accident.

Conclusions

The Board concluded that this accident could have been prevented. The Board also concluded that the contamination levels on the Swageloks® were very high, and that the accident could have resulted in much greater consequences than those actually observed. It was only the fortuitous nature of the chemical form of the contaminant that limited the consequences. Due to the manner of its formation in the inert furnace in the PF-4 glovebox, the contaminant was very anhydrous – without water. On exposure to moisture in the ambient atmosphere, the contaminant promptly absorbed the water, creating a sticky substance that strongly adhered to whatever surface it came in contact with. Therefore, outside of the immediate work area of the laser-welding glovebox, the predominant means by which the contaminant was spread was through direct contact with the worker or his clothing.

The Board concluded that the repeated handling of highly contaminated materials without any radiological controls was the **direct cause** of this accident. The Board concluded that the failure at PF-4 to evaluate the potential for contamination on the parts and to communicate that information to the Sigma staff prior to shipping the parts was a **root cause** of this accident. The Board also concluded that the failure at Sigma to ensure that the radiological condition of the parts was evaluated, and to ensure that proper radiological controls were in place before accepting the shipment was also a **root cause** of this accident.

The Board believed that there was a significant level of complacency in the LANL staff involved in this accident. It was clear that there was a high level of knowledge and experience, but the informality of operations indicated that the staffs were no longer maintaining a high level of safety awareness consistent with the Laboratory's expectations. The Board recognized that multiple previous accident investigations, regulatory enforcement actions, and other assessments over the past several years had all reached similar conclusions, and that LANL was attempting to address those concerns in a variety of initiatives. However, the Board believed that in the interim LANL and NNSA's oversight processes should have been aggressively monitoring the level of compliance in the facilities. After concluding that all of the conditions that led to this accident were latent, the Board concluded that most of those conditions could have been detected and corrected by an effective feedback and improvement or oversight program. Therefore, the Board concluded that the failure of LANL and LASO's feedback and improvement programs was a third **root cause** for this accident.

Finally, the Board concluded that LASO had not received adequate guidance or direction from NNSA Headquarters for establishing oversight goals and priorities. LASO has had significant difficulties in attracting, maintaining, and qualifying personnel for safety-related positions. Therefore, LASO redirected essentially all the safety-related staff to oversee the higher hazard nuclear facilities and some of the supporting institutional programs. LASO expected that LANL's internal oversight programs would cover the rest of the site, but LASO did not verify that those programs were adequate to accomplish that task. The Board concluded that NNSA's failure to provide LASO with adequate guidance and direction to accomplish its oversight responsibilities, and to adequately oversee LASO's implementation of its oversight program to ensure that there was an adequate balance between NNSA expectations and LASO available resources, was a **root cause** for this accident.

After reviewing the onsite and offsite responses to this accident, the Board concluded that those responses provided adequate protection of the workers, the public, and the environment. The Board recognized that during the urgency of the moment such efforts would result in less than optimal formality in the command and control processes, in the criteria applied to various situations, and in the completeness and accuracy of the documentation. However, the Board believed that several lessons could be learned from this event that could improve the planning and preparation for similar future accidents, and therefore the Board established four judgments of need to address those lessons learned.

NNSA Type B Accident Investigation of the Americium-241 Contamination Accident at the Sigma Facility, Los Alamos National Laboratory, New Mexico July 14, 2005

1.0 Introduction

1.1 Background

On July 14, 2005, a Los Alamos National Laboratory (LANL) worker (W-1) at the Sigma Facility (TA-3-66) received a shipment of uranium nitride pellets from LANL's plutonium processing facility (PF-4). The pellets had been produced at PF-4, and W-1 had been assigned the task of enclosing the pellets individually into metal cans and welding the cans shut. While unpacking the shipment, W-1 unknowingly became contaminated with americium-241. After becoming contaminated, W-1 spread the contamination to a co-worker (NMC-1) as well as to other locations within Sigma.

The contamination was not discovered until July 25, when a Radiological Control Technician (RCT) supervisor saw evidence that the radiological shipment had been unpacked without the assistance of a qualified RCT. The RCT supervisor performed a precautionary survey and found the contamination. The contamination was linked to the unpacking of a radioactive material shipment received at the facility on July 14, 2005. Significant levels of contamination were found in multiple areas within Sigma outside of radiologically controlled areas, and lower levels were detected at other onsite locations and in two LANL workers' private vehicles. Low levels of contamination were subsequently found in the homes of two LANL workers as well as in locations in Colorado, Kansas, and Pennsylvania.

During the time period between the event and the discovery, W-1 inadvertently spread contamination to various locations within Sigma, to other onsite locations, and to his home. He also provided a package of weld samples to be shipped to the Bettis Atomic Power Laboratory in Pennsylvania that was subsequently discovered to have low levels of contamination. During the period of July 15 to 17, W-1 also took a trip with his spouse to Kansas, which resulted in low-level contamination being spread to locations in Kansas and Colorado. NMC-1 spread low levels of contamination to her home. Upon discovery of the contamination, LANL responded to and controlled the onsite contamination to prevent further spread. Multiple Department of Energy (DOE) Radiological Assistance Program (RAP) teams were deployed between July 25 and August 10, and with LANL support the off-site contamination was located and effectively mitigated.

On August 15, Ed Wilmot, Manager, National Nuclear Security Administration (NNSA), Los Alamos Site Office (LASO), ordered a Type B Accident Investigation of this accident in accordance with DOE Order 225.1A, *Accident Investigations* (see Appendix A for the appointment memorandum).

1.2 Facility Description

LANL occupies approximately 43 square miles of DOE land situated on the Pajarito Plateau in the Jemez Mountains of northern New Mexico. The closest population centers are the communities of Los Alamos, White Rock, Espanola, and San Ildefonso Pueblo. The closest metropolitan center is Santa Fe, population approximately 70,000, located 35 miles away. LANL's mission has been to apply science and engineering capabilities to problems of national security. As technologies, U.S. priorities, and the world community have changed, LANL's original mission has evolved from the primary task of designing nuclear weapons to developing and applying science and technology to ensure the safety and reliability of U.S. nuclear deterrent, to reduce the threat of weapons of mass destruction, proliferation, and terrorism, and to solve national problems in defense, energy, environment, and infrastructure.

The LANL site is divided into Technical Areas (TAs) including TA-55 and TA-3. TA-55 houses chemical and metallurgical processes for recovering, purifying, and converting plutonium and other actinides into many compounds and forms. Most of TA-55 is situated inside a protected area surrounded by a double security fence. PF-4, the location where the uranium nitride shipment originated, is one of five connected buildings within TA-55 about one mile southeast of the central technical area (TA-3). PF-4 maintains extensive capability for plutonium fabrication and processing.

The Sigma Facility is located in TA-3 (see Exhibit 1.2-1) and houses metallurgical and ceramic processes used for materials synthesis, and for processing, characterizing, and fabricating metallic and ceramic items. Processes normally involve depleted uranium. Current activities focus on test hardware, prototype fabrication, and material research for NNSA's Nuclear Weapons Program as well as activities related to energy, environment, industrial competitiveness, and strategic research. The entire Sigma Facility is situated inside a protected area surrounded by a security fence.

The Regents of the University of California (UC) manage LANL under a management and operating contract with NNSA. UC has managed the Laboratory since its inception in 1943. The NNSA LASO, a part of the DOE, administers the contract with UC and oversees contractor operations at the site. The Deputy Administrator for Defense Programs (DP), NNSA, is the responsible program secretarial officer for LANL.

1.3 Organizational Descriptions

The Nuclear Materials Technology (NMT) Division is responsible for coordinating the science, engineering, technology, and nuclear facilities operations at TA-55 in support of the nation's nuclear weapons stockpile, nuclear materials disposition, and nuclear energy programs. NMT's missions include supporting national security through activities in surveillance, dismantlement, rebuild, and complex configuration. NMT also solves issues in plutonium disposition, vulnerability, and waste management to reduce the nuclear danger, and development of power sources for the nation's space program. NMT Division operates the only full-service plutonium facility in the

Exhibit 1.2-1 The Sigma Facility building in which the contamination was released.

nation and has operated this facility continuously without long-term interruption since its construction in 1978.

NMT Division is divided into several working groups based on function. The Actinide and Fuel Cycle Technologies Group (NMT-11) focuses on the challenges presented by actinide fuel and disposition technologies, including stabilization and storage of plutonium oxide materials, development of transmutation fuel forms, recovery of offsite radioactive sources, and assessment of nuclear materials for special applications.

The Nuclear Materials Management Group (NMT-4) performs a variety of security and nuclear materials control and accountability services in support of TA-55 operations. NMT-4 supports the technology groups within NMT Division by providing inventory planning and management, nondestructive assay (NDA) capability, interpreting, and implementing nuclear material control and accountability (MC&A) regulations, nuclear material shipping and receiving services, and nuclear material storage.

The Materials Science and Technology (MST) Division provides scientific and technical leadership in materials science and technology for the Los Alamos National Laboratory. MST Division is responsible for coordinating and supporting a wide range of programs, including defense, energy, environment, industrial competitiveness, and strategic research. The Division maintains state-of-the-art capabilities in materials synthesis, fabrication, characterization, processing, and modeling to help solve technical problems of national importance. MST Division includes the Materials Technology Metallurgy Group (MST-6), which focuses on materials science and engineering emphasizing metallurgical processes. MST-6 is the primary occupant and operator of the Sigma Facility.

MST-6 focuses on materials science and engineering, emphasizing metallurgical processes and research. Activities range from delivery of high quality manufactured components to fundamental materials research. Technical focus centers on the fundamental understanding of manufacturing influences on materials performance, with an extension of this knowledge through models that can either predict performance outside existing testing experience or reverse-engineer performance boundaries based on variance in processing parameters. This emphasis leads to in-depth characterization of the microstructure, composition, and performance metrics related to physical properties, homogeneity, or structural response.

To accomplish this mission, MST-6 manages an extensive materials fabrication and characterization capability. Their competence spans alloy design and development, foundry and solidification, powder metallurgy, mechanical metallurgy, welding and joining, electrochemical processing, corrosion, microstructural and mechanical characterization, and manufacturing systems to comply with full weapons production and quality rigor. These extensive capabilities make MST-6 the only metallurgical consortium of its kind in the world.

The Health, Safety, and Radiation Protection (HSR) Division works in collaboration with LANL line organizations, including NMT and MST Divisions, to make available expertise and services within the framework of Integrated Safety Management. HSR Division's mission is to provide outstanding, cost-effective health, safety, and radiation protection operational support to enable scientific and programmatic excellence, to achieve Integrated Safety Management goals, and to conduct operations in a manner that protects the worker, the public, and the environment. HSR Division is responsible for several key programs important to LANL's health and safety initiatives. Below are brief descriptions of two of these programs relevant to this investigation.

Integrated Safety Management provides the Laboratory with a comprehensive and systematic management system for setting, implementing, and sustaining safety performance and meeting environmental expectations. This system supports workers in fulfilling their safety and environmental responsibilities.

The Radiation Protection Program provides oversight and services to help ensure radiological work is accomplished safely and within requirements established by the Federal Regulation *Occupational Radiation Protection* (10 CFR 835) and enforced under the Price-Anderson Amendments Act. The program's mission is to provide for worker safety, emergency response (onsite and offsite), regulatory compliance, facility operability, and programmatic support through a combination of core, centralized, and deployed radiation protection programs, capabilities, and staff.

HSR Division includes the Health Physics Operations Group (HSR-1), which provides radiation protection support and assesses radiation protection needs for the Laboratory. HSR-1 provides direct field support to line organizations and facilitates interaction between operating personnel and other Laboratory environment, safety, and health organizations.

Other LANL organizations were also involved in various aspects of this accident. Most of that involvement was through the provision of isolated functions or services, and therefore the Board did not believe it necessary to identify them here. Those organizations will be identified as necessary within the context of the report.

1.4 Scope, Purpose, and Methodology

The Type B Accident Investigation Board began its investigation on August 16, 2005, and completed the onsite phase of its investigation on October 18. The scope of the Board's investigation was to review and analyze the circumstances of the accident to determine its causes, and to review the response to the accident. This investigation, performed in accordance with DOE Order 225.1A, *Accident Investigations*, also included an evaluation of the adequacy of the safety management systems of NMT, MST, LANL, NNSA, and DOE as they relate to the accident. The purposes of this investigation were to determine the causes of the accident, to identify lessons learned, and to reduce the potential for similar accidents at LANL and across the DOE complex. The Board conducted its investigation using the following methodology:

- Inspecting and photographing the accident scene and individual items of evidence related to the accident.
- Gathering facts through interviews, document and evidence reviews, and inspections of the area.
- Conducting technical evaluations of items of evidence, as appropriate (technical evaluations were conducted by LANL personnel under Board direction).
- Reviewing the initial response actions taken by LANL and NNSA.
- Using events and causal factors analysis, barrier analysis, and change analysis to correlate and analyze facts and identify the accident's causes (see box).
- Developing judgments of need for corrective actions to prevent recurrence based on analysis of the information gathered.

As part of this investigation, the Board was also tasked to conduct a detailed evaluation of the manner in which LANL and NNSA responded to the dispersal of contamination to both onsite and offsite locations. In reviewing these activities, the Board realized that actions taken during the response phase could not reduce the probability of the accident, nor could they effectively act as mitigation for the impacts, since the widespread loss of control had already occurred. Therefore, the Board elected to identify any concerns identified in the response activities as Lessons Learned rather than using the traditional term of Causal Factors, in order to separate those concerns from the conditions that the Board determined to have been causal factors leading to the accident. However, the Board did elect to develop judgments of need for the Lessons Learned using the same processes that were applied to the causal factors.

Accident Analysis Terminology

A ***causal factor*** is an event or condition in the accident sequence that contributes to the unwanted result. There are three types of causal factors:

- **direct cause**, which is the immediate event(s) or condition(s) that caused the accident;
- **root cause(s)**, which is (are) the causal factor(s) that, if corrected, would prevent recurrence of the accident; and
- **contributing causes**, which are causal factors that collectively with other causes increase the likelihood of an accident, but that individually did not cause the accident.

Events and causal factors analysis depicts the logical sequence of events and conditions (causal factors) that allowed the event to occur, and facilitates the use of deductive reasoning to determine events or conditions that contributed to the accident.

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

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

The Board also uses specific terminology in some sections of the report to emphasize particular features of the investigation. When the Board makes a **determination**, it is a means of designating a decision by the Board that an item is a fact, based on evidence analyzed by the Board. When the Board expresses a **belief**, it is stating an opinion on a topic. A **conclusion** is a determination that the Board decides has direct bearing on the investigation. Finally, a **concern** is a determination that the Board decides may have relevance to the investigation or may be indicative of an issue that extends beyond the scope of the investigation, but either the relevance or the evidence is not strong enough for the Board to draw a firm conclusion.

2.0 Discussion of the Accident

2.1 Room R3 in the Sigma Facility

Room R3 is located in the southwest corner of the basement of the Sigma Facility. The room is rectangular in shape with the long axis in a north-south direction (see Exhibit 2.1-1). Room R3 contains a number of optical tables and other equipment used primarily for laser operations. Partitions and curtains divide the room into more discrete work areas. Workbenches, desks, and storage cabinets are found in various locations. A water fountain and sink are near the primary entrance in the south end of the room. A secondary door is on the north wall and provides access to other basement areas. Two gloveboxes are in the far northeast corner of the room. Glovebox 1 (herein referred to as the "laser welding glovebox") is the location where the Uranium Nitride pellets, contained within Swagelok® couplings, were placed (see Exhibit 2.1-2).

Exhibit 2.1-2 The uranium nitride pellets were contained within Swagelok® couplings and sealed with end caps to maintain an inert atmosphere.

Both gloveboxes are designed to provide controlled, positive pressure, inert atmospheres for laser welding. The ventilation systems are designed to recirculate the glovebox atmosphere through a High Efficiency

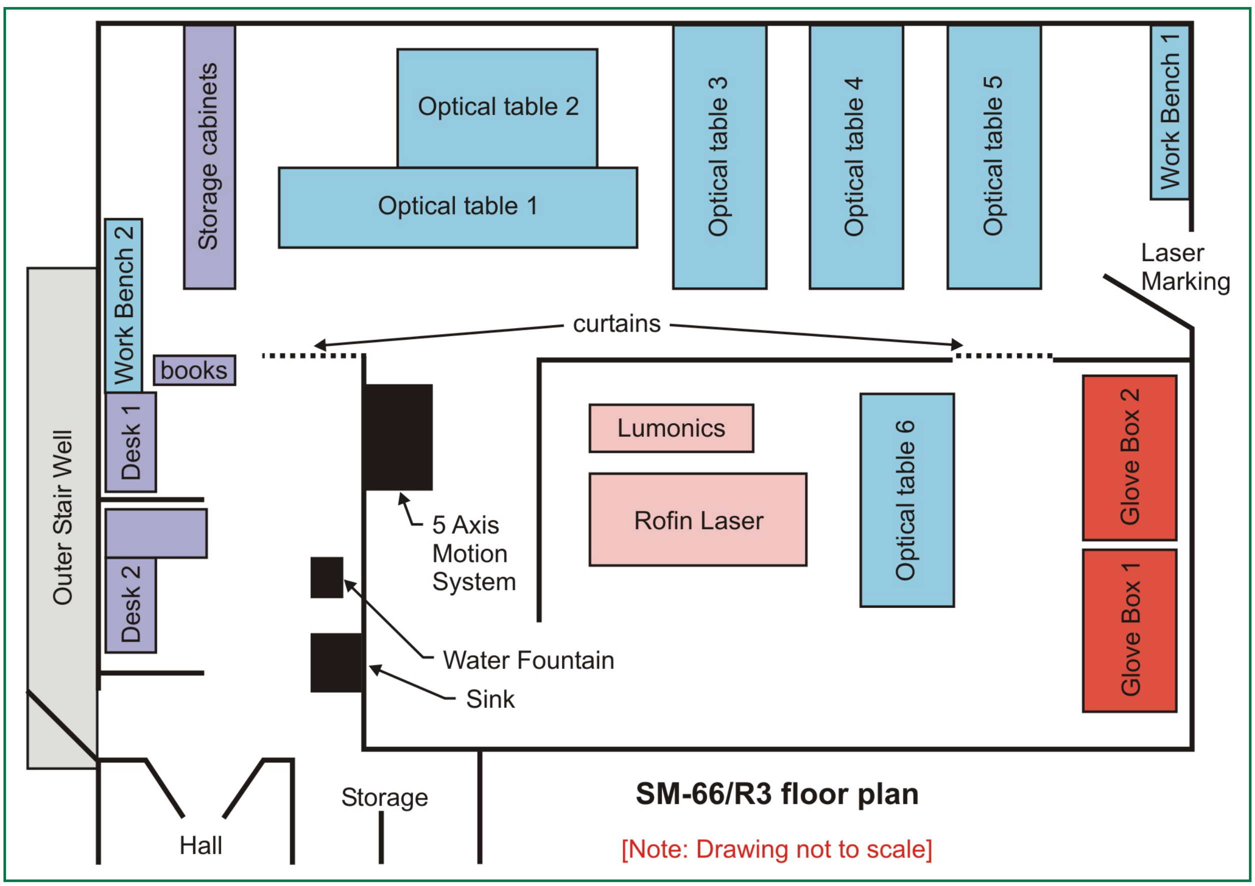


Exhibit 2.1-1 The floor plan for room R3 in the Sigma Facility. The Swageloks® were placed into glovebox 1.

Particulate Aerosol (HEPA) filter to control fumes generated during welding operations. The gloveboxes were not specifically designed for radiological applications, but are able to provide control of limited quantities of radioactive contamination. In order to maintain the quality of the inert atmosphere, each glovebox has a double-door antechamber for introduction and removal of materials. Vacuum pumps are installed to purge the antechamber and to operate the ventilation systems within the gloveboxes.

2.2 Rooms 126, 127, and 128 in PF-4

Rooms 126, 127, and 128 are located in the Plutonium Facility (PF-4) in TA-55. Room 126 contains glovebox lines that are used to process uranium and other actinide radioactive materials into reactor fuel pellets for research and development testing. The production of the different fuel pellets is conducted in separate batches to minimize the level of impurities in the fuel. Individual gloveboxes are interconnected to allow movement of material between workstations, and a negative pressure inert atmosphere exhausted to a multi-stage HEPA filtration system controls radioactive contamination. The uranium nitride pellets were fabricated in this glovebox line, and the pellets were loaded into the Swagelok® couplings in glovebox G138 in this room (see Exhibit 2.3-1). The gloveboxes are connected to an enclosed trolley system that allows movement of materials in a radiologically controlled manner throughout PF-4, and particularly between the gloveboxes in room 126 and room 128.

Room 127 is a small connecting room between 126 and 128. It is used for administrative purposes and contains file cabinets and a safe. Accountable material is temporarily stored in a secure manner in the safe. After packaging and removal from the glovebox line, the Swagelok® couplings containing the uranium nitride pellets were temporarily staged in the safe pending transfer to NMT-4 for packaging and shipping.

Room 128 is where the trolley system terminates into a glovebox. The glovebox is connected to an open-front hood to accommodate the introduction and removal of material and equipment into and out of the glovebox system. The Swagelok® couplings containing the uranium nitride pellets were packaged into the plastic bags, taped, and removed from the glovebox system here.

2.3 The Event

LANL was subcontracted by the Bettis Atomic Power Laboratory to fabricate uranium nitride pellets in support of Bettis' contract to NASA for space reactor research and development activities. The pellets contained 14% enriched uranium, and were to be welded individually into special cans. Once fabricated, 18 pellets were placed in 9 Swagelok® containers in glovebox G138 in preparation for shipping them to Sigma for welding into the cans. On July 7 the Swageloks® were sealed inside a plastic bag, which was then moved through the trolley system into glovebox G150 in room 128. The bag was then wiped down with wetted cheesecloth to reduce the contamination on the outside of the bag. No attempt was made to reduce the contamination on the Swageloks® themselves. The Swageloks® were then moved to hood X110 and placed inside two additional plastic bags as they were removed from the hood. Exhibit 2.3-2 illustrates the sequence of the bagging process. Each bag was wiped down with wetted cheesecloth and the

Exhibit 2.3-1 Glovebox G138, where the uranium nitride pellets were loaded into the Swagelok® couplings.

Exhibit 2.3-2 A simulation of the sequence of packaging the Swageloks® in plastic bags. It was later determined by LANL that only three bags were used.

outside of each was monitored for contamination. The plastic bags were found to be free of detectable contamination. The results of these surveys were not documented. Once the packages were removed from the glovebox line, they were placed inside a Hagen can (a Hagen can is a LANL-designed robust filtered and vented container used for containing radioactive material within the facility, see Exhibit 2.3-3). The Hagen can was labeled as containing radioactive material and measured dose rate values of 1 millirem per hour beta-gamma and 0.2 millirem per hour neutron were noted on the can's label. A Tamper Indicator Device (TID) was attached to the Hagen can, and it was temporarily stored in the safe in room 127 pending final packaging and shipment to Sigma.

On July 12, the Hagen can was transferred to NMT-4 for final packaging in a Type A shipping container (see Exhibit 2.3-4). Following insertion of the Hagen can, the Type A container, which is a thirty-gallon drum, was surveyed and labeled with a White I Radioactive Material shipping label. A Health Physics Radioactive Material Survey tag and TID were attached to the outside of the drum. The drum was found to be free of detectable contamination and no radiation levels were detectable on the surface of the drum. A Radioactive Material Transfer Form was then prepared for the shipment.

On July 14, the drum containing the Swagelok® containers was transported by the Hazmat Packaging and Transportation Group, SUP-5, to MST-6 at Sigma. The shipment was received by the nuclear material custodian, NMC-1, and the transfer of the material was recorded in the LANL Material Accountability Security System (MASS). W-1 retrieved the package from NMC-1 and moved it to room R3. Exhibit 2.1-1 depicts the general layout of the room. W-1 then removed the Hagen can from the thirty-gallon drum and placed it inside the laser-welding glovebox. Prior to this date, W-1 had prepared four weld coupons in the laser-welding glovebox, and those coupons were removed from the glovebox prior to introducing the Hagen can. Also, prior to the introduction of the Hagen can, there had never been any radioactive material in the glovebox. W-1 then removed the multi-layered plastic package from the Hagen can. Once the package was removed from the Hagen can, the Hagen can was transferred out of the laser-welding glovebox

Exhibit 2.3-3 The Hagen can that was used for transferring the uranium nitride pellets from PF-4 to Sigma.

Exhibit 2.3-4 The Type A shipping drum and packing material that was used to transfer the uranium nitride pellets to Sigma. The drum was found in room R3 behind glovebox 2.

and a knife was introduced into the glovebox to cut the plastic bags. W-1 removed the 9 Swagelok® containers from the bags and performed an inventory of the contents by verifying the serial numbers against information provided by NMC-1 (see Exhibit 2.3-5). W-1 then removed the knife and bags from the glovebox. W-1 returned the knife to the sheath on his belt and placed the plastic bags on a nearby optical table. There was no contamination survey equipment in the immediate area; W-1 reported that at this time he went to a contamination frisker in another room of the building (R108), frisked himself, and did not detect any contamination. Once the serial numbers were verified, W-1 returned the MASS transaction form to NMC-1. W-1 then secured the work area and left the site for a 3-day weekend. The MASS custodian accepted the paperwork and placed the document under a plastic desk cover in her office to keep from misplacing it. Later that day, NMC-1 alarmed a hand and foot monitor while exiting a radiologically controlled area elsewhere in Sigma. After setting off the alarm, NMC-1's supervisor suggested that she wash her hands and re-monitor. The resulting measurement was negative, and the incident was never reported.

2.4 Pre-Discovery Activities

From July 15 through July 17, W-1 traveled with his spouse (currently living in Lakewood, Colorado) to Great Bend, Kansas, to visit a relative. W-1's spouse met him at his residence, and they drove in the spouse's vehicle to Great Bend, and stayed at a hotel during the visit.

On July 18, W-1 returned to work at Sigma. During that week, W-1 performed several tasks in the facility that included welding of some empty cans in the laser-welding glovebox in R3 for testing. The Swagelok® containers were in the laser-welding glovebox, but they were not used in this work evolution. After the empty cans were welded, they were removed from the glovebox and taken to R108 for high-temperature environmental conditioning and leak testing. The work involved the use of several pieces of equipment in R108, including electron beam welders, laser welders, and furnaces. A total of four cans were fabricated.

On July 20, an NMT-11 employee, W-2, arrived at Sigma in his personally owned vehicle (POV) to assist

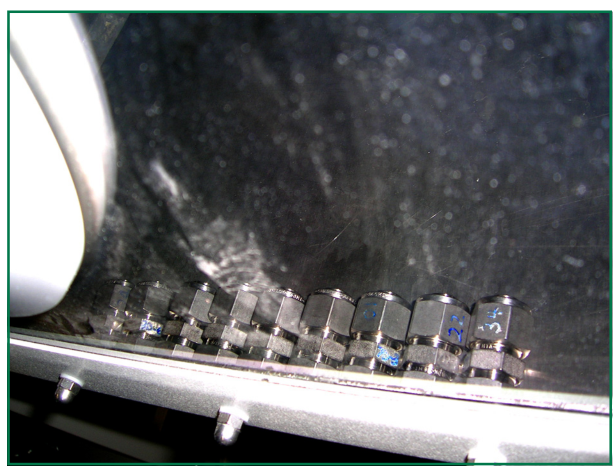


Exhibit 2.3-5 The Swagelok® containers found inside the laser-welding glovebox in R3. Note that the Swageloks® were marked with serial numbers for the individual pellets.

W-1. As previously arranged, W-1 provided a package of two of the weld coupons that were welded prior to July 14 to W-2 for shipment to Bettis in Pittsburgh, Pennsylvania. Since these coupons were believed to be non-radioactive, W-2 verified the package contents, placed the package in his POV, and transported the package to the SM-30 shipping facility. At the warehouse, personnel opened the package to add some packing material, and then shipped the package via Federal Express. On July 21 Bettis received the package.

On July 21, W-1 notified the Radiological Control Technician Supervisor (RCTS-1) that he needed to make preparations for welding the uranium nitride pellets into their containers in the laser-welding glovebox in room R3. Prior to this event, no radiological operations had ever been conducted within this glovebox. RCTS-1 advised W-1 that the glovebox would have to be posted to allow for work on radioactive material. At this time, the RCTS-1 learned that the package had been received by W-1. RCTS-1 reminded W-1 that an integrated work document (IWD) was necessary for the planned work. The IWD was written that day and subsequently approved the next day.

2.5 Discovery

On July 25, RCTS-1 went to room R3 to post the laser-welding glovebox, and she inadvertently found a used radioactive material transfer tag in the sanitary trash. RCTS-1 then found the empty Type A drum sitting in the room and realized that the package had been opened. Prior to this discovery, RCTS-1 was unaware that the initial package had been opened. RCTS-1 was concerned about potential contamination, and she returned to her office and obtained radiological surveillance equipment to evaluate the radiological hazards in room R3. The initial radiological survey indicated total alpha contamination of 600,000 dpm/100-cm^2 and 118,000 dpm/100-cm^2 removable alpha contamination on the handle of the glovebox antechamber door. RCTS-1 then directed one of the radiological control technicians, RCT-1, to survey W-1. W-1 was found to have levels of 9,000 dpm alpha contamination on his right thumb and his identification badge, and 18,000 dpm on his dosimetry badge.

2.6 Onsite LANL Response

On July 25, once the initial surveillance information was reviewed, it was determined that the ratio of alpha activity to beta-gamma activity was inconsistent with the type of radioactive material normally encountered within Sigma. RCTS-1 instructed RCT-1 to take W-1 to the basement area and commence decontamination efforts. Essentially parallel to this activity, RCTS-1 contacted her team leader, RCTS-2, to advise him of the situation, to request additional RCT support, and to obtain additional radiological instrumentation to allow for further characterization of the facility. In this same time period, MST and HSR management, the Associate Director, and the LANL Director were notified of the discovery.

An additional RCT (RCT-2) and RCTS-2 arrived at Sigma with the additional instrumentation. RCTS-1 ordered nasal smears on W-1, RCT-1, and herself. RCTS-1 also took samples for isotopic analysis to determine what radionuclide was present. During this time frame, several surveillance activities and isolation activities were being conducted simultaneously. At about noon, decontamination activities were complete on W-1. An alpha portal monitor indicated that W-1 had no detectable contamination on his person. Paperwork was completed to allow for analysis of the nasal and area smears. RCTS-2 and RCT-2 conducted large area wipes on floor surfaces in and around the affected area to attempt to determine the location and magnitude of the radiological hazards. Within the areas surveyed by large area wipe techniques, removable contamination was identified at levels of 4,000 dpm. It is important to note that while the surveillance activities were taking place several additional personnel had arrived at the scene and the affected areas had not been completely secured. HSR-1 did not have radiological posting signs immediately available at Sigma since they are printed as needed; so, several makeshift boundaries were established temporarily to prevent personnel entry in to these areas until the appropriate postings could be generated. RCTS-1 removed all unnecessary personnel from the scene.

Once the initial HSR-1 responders believed that the affected areas were controlled, the response then focused on a survey of areas where W-1 could have cross-contaminated the facility. RCTS-1, RCTS-2,

What is Americium-241?

Americium-241 (Am-241) is a man-made radioactive silver-white metallic element with 95 protons and 146 neutrons in the nucleus of its atom. The element primarily decays by emitting an alpha particle, and its radioactive halflife is 432.7 years. Am-241 is normally produced by bombarding Plutonium-239 (Pu-239) with neutrons. Pu-240 is created with the capture of one neutron, and it then captures a second neutron to form Pu-241. The Pu-241 then decays to Am-241, which is chemically separated from the plutonium.

Am-241 is used in a number of research, industrial, and medical processes. The use of Am-241 in ionization chamber smoke detectors is its most widely known application. A typical ionization smoke detector contains one microcurie of Am-241 (about 0.3 micrograms). The Am-241 is incorporated into a gold matrix that is then sandwiched between silver and palladium, fixing the Am-241 while allowing the alpha particles to pass through the materials. The alphas ionize the air between two charged plates allowing a small electrical current to flow. Smoke entering the detector reduces the current flow and sets off the alarm.

The design of the Am-241 source in smoke detectors eliminates the possibility of the radioactive material being dispersed into the surrounding environment during normal use. Before approving the use of Am-241 in commercial products such as smoke detectors, the Nuclear Regulatory Commission (NRC) assessed several scenarios to determine the potential exposure to personnel transporting, stocking, using, or responding to fires in facilities using or storing smoke detectors. Doses calculated for these individuals were less than 1 mrem effective dose equivalent (EDE) per year. The NRC also estimated that if a person intentionally swallowed the Am-241 source contained in a smoke detector, the resulting dose would be about 600 mrem (EDE). This can be compared to the annual exposure limit for workers of 5,000 mrem per year or the U.S. average annual dose due to natural radiation of 300 mrem per year.

In contrast, the total contamination present in this accident was almost 4,000 microcuries (equal to about 4,000 smoke detectors), and was in a finely divided particulate form that could be easily inhaled. If an individual were to inhale the equivalent of one smoke detector's worth of Am-241 in this form the resulting dose could be as much as 100,000 mrem Committed Effective Dose Equivalent (CEDE). Fortuitously, after exposure to the atmosphere the contamination tended to absorb moisture and adhere to the surfaces it came into contact with, so the actual dose to the worker was much lower than this hypothetical scenario.

RCT-1, and RCT-2 deployed to W-1's office to ascertain radiological conditions. The survey of the office indicated radiological contamination on a number of items, including W-1's keyboard and desk that were contaminated up to 10,000 dpm/100-cm^2. Other items within the office were contaminated up to 4,000 dpm/100-cm^2. Additional large area wipes were conducted in main hallways in and around W-1's office. The results of the hallway surveys were negative. At this time, the analysis of the samples came back from the Health Physics Analytical Laboratory (HPAL) and the contaminant was determined to be Americium-241 (Am-241). Contamination from Am-241 was completely unexpected at Sigma, as it was outside of their normal operating experience and there was no knowledge that the isotope had been brought into the facility. Because the event was discovered early on the morning of July 25 and W-1 had not yet had time to do any work on that day, HSR personnel realized that W-1 was likely contaminated the previous week, and began considering the possibility of contamination beyond LANL boundaries. A DOE Radiological Assistance Program (RAP) Team was requested to survey the home of W-1 for possible contamination (see Section 2.7).

On July 26, a critique of the incident was held to discuss the event, to determine occurrence-reporting requirements, and to get an up-to-date status of Sigma. Available information indicates that approximately 40 people were present at the critique. Based on the survey information received from the initial RAP response, it was determined that W-1 had indeed contaminated his residence in White Rock, New Mexico. At the direction of the Deputy Laboratory Director, the Deputy Associate Director for Strategic Research was assigned to lead an ad hoc management team to manage the response. The team included management representatives from the multiple organizations that would be involved in the response activities. It was decided that workers in Sigma would be sent home while further surveys were conducted to characterize facility conditions and to provide an opportunity for decontamination where necessary. The ad hoc management team also decided that all personnel would be monitored for contamination prior to their release. A total of 162 employees were monitored using an alpha portal monitor and hand-held monitors. The results of this monitoring effort indicated that all 162 personnel were free of detectable contamination.

Additional RCT support was provided to assist HSR-1 personnel at Sigma. Surveillance activities continued to be conducted in room R3 and surrounding areas. The results of the additional surveys in room R3 indicated additional contamination levels up to 10,000 dpm/100cm^2. The surface of the ventilation system intake in room R3 was surveyed and the results were less than detectable activity. A Continuous Air Monitor (CAM) and a high volume air sampler were placed inside the room.

By July 27 and continuing for several days thereafter, site personnel that had been inside Sigma since the

What is radiological contamination?

Radiological contamination is radioactive material, typically in particulate form, which is in an undesired location such as on personal clothing or skin, or in public areas. Uncontrolled contamination represents a potential for personnel exposure through one or more mechanisms. Sometimes the radiation emitted from contaminated skin, clothing, or surrounding materials can directly expose personnel. More commonly, such contamination can be inhaled, ingested, or absorbed through the skin or an open wound, resulting in radioactive material being taken into and irradiating specific organs such as the lungs, bone, or thyroid.

Two basic methods are used to measure radiological contamination. Radiation detectors measure the total amount of contamination deposited on a surface, and swipe samples measure the portion of the total contamination that is removable. A swipe sample is taken by rubbing a special type of paper, the swipe, across the surface being sampled and this swipe is then measured to determine how much contamination has been collected. The two measurements together provide information used to assess the potential for both external and internal exposure. The primary concern is how much of the contamination may be easily disturbed or picked up by casual contact resulting in inhalation or ingestion exposures. This contamination may also be easily carried from its point of origin to other locations such as the workers office or home.

The DOE has established criteria for the levels of contamination that can be allowed in different areas, and has specified methods for controlling work in contaminated areas. Engineering controls such as barricades, gloveboxes, and specially designed ventilation systems are used to contain the contamination within a specific work location. Administrative controls such as warning signs and radiation monitors are used to prevent the spread of contamination from radiological work areas. Workers in these areas typically use personal protective equipment, such as respirators and anti-contamination clothing, to protect themselves from exposure to radioactive materials and to minimize the spread of contamination outside of the controlled area.

Radioactive contamination is typically measured in terms of the amount of radioactivity per unit area. In this report, this quantity is expressed in the unit of "disintegrations per minute per 100-cm^2", or dpm/100-cm^2. Since Am-241 is mainly an alpha emitter, it is inferred that all measurements are for alpha emissions. In some cases, when the size of the contamination is either smaller than a 100-cm^2 area, or when the measurement is expressed as total activity on the sample, the units will be expressed as either dpm or millicuries (1 millicurie equals 2.2 x 10^9 dpm).

incident and prior to its discovery began requesting radiological surveys to ensure they were not contaminated. During conversations between an HSR-1 manager and the MST-6 Group Leader, a concern was raised that it had not been verified that the bags the Swagelok® containers were originally shipped in had been accounted for to ensure they were being controlled to prevent further spread of contamination. MST and the Sigma RCTs developed the IWD and the Radiological Work Permit (RWP) to allow for entrance inside room R3 to verify the location of these bags.

During discussions with W-1, MST management became aware of the weld coupons that were shipped to Bettis. Initial conversations indicated that the coupons had been prepared and removed from the glovebox before the contaminated Swageloks® were introduced, and therefore the samples were believed to be clean. A day later, W-1 recalled that he had handled the parts after July 14 in order to prepare them for shipping. Based on that recollection, there was now a concern that the samples might be contaminated, and a MST Team Leader contacted Bettis to notify them of the situation. Bettis personnel then surveyed the samples and low levels of alpha contamination were detected. The measurements conducted at Bettis indicated that the total contamination was approximately 3100 dpm, and that it was predominately Am-241 with a small amount of Pu-239.

Late in the afternoon on July 27, entry was made into room R3 to look for the bags that had contained the Swageloks®. Due to the high contamination levels measured, the RCTs quickly identified the trashcan containing the bags. The trashcan and its contents, including the packing bags, were inserted into a large bag. Visual examination identified a bundle of plastic bags that was identified as the package in which the Swageloks® had been shipped. Numerous photos were also taken during this entry to document the condition of the room at that time (see Exhibit 2.6-1 through 2.6-4).

On the evening of July 27, the management team decided to have Sigma employees return to work the following day. On July 28, while continuing to use

Exhibit 2.6-1 The general work area of R3 where the accident occurred. The laser-welding glovebox is the box in the far corner of the rrom. Opposite to it is the optical table where W-1 initially placed the plastic bags. (The posting, anti-contamination clothing, and ladder were introduced during response activities.)

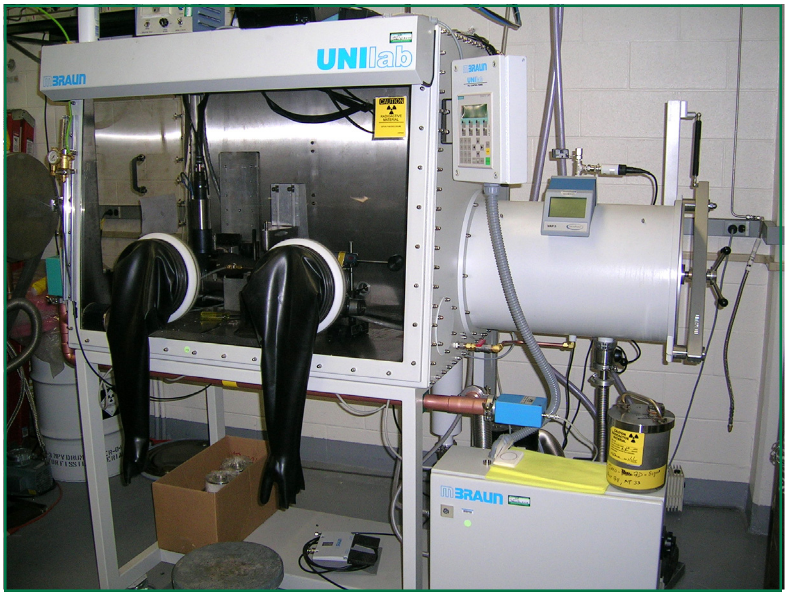


Exhibit 2.6-2 The laser-welding glovebox in room R3 as found during initial re-entries by LANL. The chamber on the end of the glovebox is the antechamber through which items are passed in and out of the box.

outside support, RCTS-2 focused the work activities on completing a characterization of radiological conditions in the facility. The emphasis of those activities continued to focus on an ergonomic survey coupled with knowledge of where W-1 had been or with whom he may have come in contact as a result of his work activities. Parallel to this effort, RCT-2 was assigned to perform surveys in R108. While it was understood by response personnel that equipment in room R108 was used by W-1 on a regular basis, HSR-1 personnel were not sure if this area had been evaluated to a reasonable extent. The results of the surveys in room R108 indicated several areas of contamination. Based on testimony, the level of contamination and the physical characteristics of the contaminant came as a surprise to the survey team. Fortunately, the contaminant seemed to be fixed with little removable activity. Additionally, the handle of a contamination frisker probe in R108 was contaminated to levels of 2,000 dpm/100-cm^2. There was no evidence of contamination on the face of the probe instrument. Access to R108 was restricted at this time.

As a result of the new findings and recognition that personnel had been allowed back into the facility, considerations were taken to evacuate the facility for the second time. HSR-1 staff expressed concern in staging another evacuation. Based on testimony, the logic used not to evacuate the facility again was to keep personnel within the facility so that they could assist in further determining with whom W-1 had interacted during the total timeframe of the incident. Later in the afternoon, RCTs again made entry into R108 to perform additional characterization of the area. These surveys indicated numerous locations of total alpha contamination with levels up to 50,000 dpm/100-cm^2 in R108. Specific locations of contamination were conspicuously marked to assist in decontamination efforts. Review of the survey documents indicated no detectable removable contamination present. Based on follow-up conversation by the Board with RCTS-1 and RCTS-2, it was determined that removable surveys of the area were not actually taken; as such, the removable

Exhibit 2.6-3 The trashcan where the radioactive material tag was discovered. The taped bags are the packaging material used to contain the Swageloks. Also note the discarded small brass can, which is one of the tamper indicating devices.

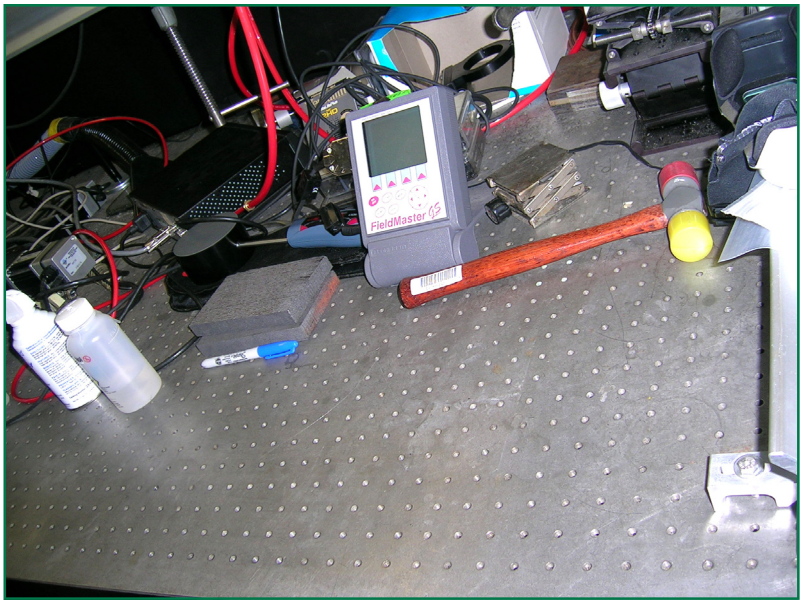


Exhibit 2.6-4 The optical table in R3 where W-1 placed the plastic bags before disposing of them. High levels of contamination were found in this area of the table.

requested three hand and foot monitors be placed at the exits of Sigma. Shortly after the hand and foot monitors were in place, two individuals alarmed the monitors. According to testimony, the contamination level that would trigger the alarms was approximately 1,000 dpm. Samples of the contamination on the individuals indicated that the radionuclide was Am-241. Due to the fact that there were no alpha detecting floor monitors available at Sigma at this time, they were requested from another facility.

From August 2 to August 5, radiological surveys were conducted on an ongoing basis within Sigma. Some incidental contamination was found during this time, but it did not appear to be uniform and continued to be somewhat reflective of places where W-1 had frequented. Because of the urgency to complete the surveys and respond to immediate requests, the surveys conducted between July 25 and August 5 were not formally documented until August 5. At this time, the individuals involved in the activities came together in an attempt to formally document, to the extent possible, the information that had been gathered.

component was not initially evaluated. Due to the urgency to accomplish all of these tasks, this survey was not formally documented until August 2.

At the same time, the HSR-1 staff was being drawn in several directions by Sigma personnel who were concerned about the possibility of contamination of individual workplaces. It was during this period that RCT-1 was contacted by NMC-1 to make him aware of the fact that on July 14 W-1 had given her a piece of paper after verifying the serial numbers of the parts. NMC-1 provided the paper to RCT-1, and it was found that the paper was contaminated at 1,000,000 dpm/100-cm^2.

Parallel to surveillance activities from July 28 through August 2, HSR-1 management recognized that the surveys conducted from the time of discovery were performed primarily within the facility. It was understood that between July 14 and July 25, W-1 had been at a number of areas outside the confines of the facility. As a result, broader surveys to include facilities that W-1 had frequented such as guard portals and other areas were recommended. Based on testimony, all areas surveyed in support of these recommendations indicated no detectable contamination. In addition, the Radiation Protection Program Manager (RPPM-1)

On August 3 and again on August 9, entries were made into R3 in an effort to verify that all of the plastic bags used to ship the Swageloks® were accounted for. NMT-11 had attempted to determine the exact number of plastic bags used to package the shipment, but could not determine whether 3 or 4 plastic bags had been used (see Exhibit 2.3-2). During the entry on August 3, RCT's were able to identify the presence of only two plastic bags due to difficulties in seeing the bags through two layers of plastic bags encasing the trash. During the entry on the August 9, RCTs were able to verify the presence of the third plastic bag when it was determined that one of the "pigtails" (the taped ends of the bags) was nested inside of another. LANL concluded that there was no fourth bag.

From August 6 through August 19, continuing efforts were made by HSR-1 personnel to characterize and decontaminate room R108. Decontamination personnel from the Nuclear Waste and Infrastructure Division conducted the work and were provided continuous RCT coverage. Portions of the room were decontaminated to allow for access to the area for production purposes. On August 19, RCT-3 performed a post-decontamination survey of R108 and found that removable alpha contamination met the release criteria of less than 20 dpm/100-cm^2.

Contamination found in other areas of Sigma was also decontaminated and contaminated objects were removed when discovered. W-1 and NMC-1's offices were in the process of being surveyed and decontaminated when this accident investigation Board assumed control of the rooms as part of the accident scene, and therefore had not been released yet.

2.7 Offsite LANL/RAP Response

Following identification of contamination on W-1 and the recognition that the contaminating event had likely occurred the previous week, LANL determined that a radiological survey of the home of W-1 was necessary. In the afternoon of July 25 formal request was made for the team to deploy to the home to conduct radiological surveys. Following logistical preparations and approval by LANL management and the Headquarters Emergency Response Organization (ERO), the DOE RAP Team deployed to the home and arrived on the scene at 4:30 pm. The objective of the survey was to determine whether or not the home had actually been contaminated. Once contamination was confirmed, the final surveys and actual decontamination work was to be completed by a LANL decontamination team. Direct measurements taken in the garage immediately after arrival detected the presence of alpha contamination. Direct alpha readings as high as 1,600 dpm/100-cm^2 were discovered in the garage with the highest readings being identified on a computer mouse pad. Swipe results for the mouse pad indicated 415 dpm. Surveys in the home identified contamination levels to a maximum of 6,000 dpm/100-cm^2 with removable levels to a maximum of 710 dpm. The highest levels in the home were discovered on an easy chair in the living room. Portable gamma spectroscopy of some contaminated items indicated that the contamination was Am-241.

As previously mentioned, a critique of the incident was conducted on July 26. After the fact finding meeting, the group (the ad hoc management team discussed above) broke up into two separate subcommittees with one discussing onsite concerns and activities and the other discussing offsite concerns and activities. The offsite group discussed the possibility for other RAP deployments offsite. During the discussion, it was recognized that a computer keyboard in W-3's office was contaminated. W-3 then requested that his home be surveyed to check for contamination. The meeting was concluded and preparations were initiated for deployment of the RAP Team to W-3's home. At the home, direct reading and swipe surveys were conducted and no activity was identified. The surveys focused on areas most likely to become contaminated from W-3's routine activities. A total of 28 swipes were taken within the home for lab analysis, with all results indicating no detectable activity. These results were communicated to W-3.

On July 27, a decontamination team arrived at the home of W-1 to complete a more thorough characterization of the contamination in the home and to begin cleaning up the contamination or removing the contaminated items from the home. This team included representatives from Emergency Management and Response (EM&R), RAP, HSR-1, Property, Transportation, and Waste Management. The team began by first removing contaminated items identified by the RAP Team from the home. A list of items was documented and the items were packaged for disposal. The team then initiated a thorough characterization of the home and removed additional furnishings identified as contaminated. A final survey was conducted to verify that the home was free of detectable contamination. Swipes from these surveys were submitted to the Health Physics Analytical Laboratory (HPAL) for analysis. After reviewing the swipe results from HPAL on July 28, it was determined that the bathroom sink in W-1's home was still contaminated. Arrangements were made for the HSR-1 clean up team to return to the home and the sink was successfully decontaminated.

At Sigma, the discovery of the piece of contaminated paper in NMC-1's office prompted a request to survey NMC-1's home. In addition, deployments to Lakewood, Colorado, and Great Bend, Kansas, were discussed after it was determined that W-1 had traveled to Kansas with his spouse using her vehicle. Efforts were initiated to assemble personnel and equipment to support deployment to these three locations. Surveys conducted in Sigma in the early afternoon also identified two additional workers whose homes were surveyed as a precaution.

A RAP team was deployed to the home of NMC-1 and arrived at the home in the early evening. Both direct radiation measurements and swipe surveys were conducted. Direct measurements taken at the home did not detect any contamination. However, following analysis of the 20 swipe samples by HPAL on July 29, one swipe taken in the sink in the master bedroom indicated removable contamination levels of 430 dpm. Two RCT's from HSR-1 returned to the home to decontaminate the sink and to conduct additional surveys to check for contamination. The sink was successfully decontaminated and all direct and swipe survey results were negative including the analysis of the swipe samples by HPAL. This information was communicated to the employee and the home was declared free of detectable contamination.

On July 29, the RAP team assembled and departed for the Ross Aviation Hangar in Albuquerque. The LANL team met up with the DOE Team Leader and departed for Lakewood, Colorado. The team arrived at the home at 12:45 pm. Two State of Colorado personnel from the Hazardous Materials Waste Management Division accompanied the team during the survey of this home. Radiological surveys located contamination in the vehicle used for the trip, on a suitcase, and on a pouch. Maximum levels in the vehicle were 2200 dpm on the driver's seat armrest cover and 2000 dpm on the driver's seat cover. The suitcase was contaminated at 1000 dpm and the pouch at 200 dpm. These items were all removed and packaged for transport back to Los Alamos for permanent disposal as radioactive waste. Other items identified as contaminated were successfully decontaminated. Swipe samples were counted in the field and then returned to Los Alamos for analysis by HPAL. The final survey results indicated the home was free of detectable contamination. Plans were also being finalized for surveys to be conducted in Great Bend, Kansas.

On July 29, other RAP teams conducted surveys at the homes of the two additional Sigma employees whose offices had been contaminated. Following direct radiation measurements and the collection of 35 swipe samples, the home was determined to be free of detectable contamination. For the second home, direct surveys could not be conducted due to the high radon levels present in the home (the home included a large basement). For this home, a total of 43 swipes were collected in the home and an additional five were collected from the worker's car. All swipes were found to be free of detectable contamination.

On July 30 the RAP team in Lakewood departed for Great Bend and arrived there at 1:20 pm. Following lunch, the team coordinated with the homeowner to conduct a survey of the home. Contamination was located on a radio, furniture in the living room, kitchen range, garage refrigerator, and shop sink. Contamination levels ranged from 300 dpm/100-cm^2 to 2400 dpm/100-cm^2. Items were decontaminated or packaged for disposal as radioactive waste. A State of Kansas representative was briefed on the findings and activities of the response team.

On August 5, NNSA Headquarters senior managers requested that a RAP team deploy back to Great Bend, Kansas, to survey the hotel room used by W-1 during his stay there in mid July. The RAP team assembled at the Ross Aviation Hangar in Albuquerque the next morning, and arrived at the hotel at about 2:00 pm. Direct and removable radiation measurements were taken in the room previously occupied by W-1. Two chairs were contaminated at levels of 800 and 1600 dpm/100-cm^2. The contaminated portions of the chair were cut out and the contaminated materials packaged for disposal. The remainder of the chairs were verified as being free of detectable contamination and disposed of as sanitary trash.

On August 9, W-1 requested that additional surveys be conducted at his home in White Rock, New Mexico. A meeting was conducted with W-1 to determine what additional surveys were being requested. Items identified included tools and clothing he had worn while changing the oil in his spouse's car on July 14. Direct and swipe surveys conducted at the home identified contamination on a duffel bag containing the clothing, two wrenches, and two trash receptacles. The wrenches and duffel bag were packaged for disposal as contaminated waste and the trash receptacles were successfully decontaminated. Analysis of swipe samples by HPAL identified one swipe from one of the trash receptacle with 12 dpm of alpha activity. This was below the 20 dpm/100-cm^2 release criteria cited in 10 CFR 835 so no further action was taken.

2.8 Consequences

The consequences of the July 14 incident included impacts to personnel and facilities. Personnel consequences included potential health risk to exposed individuals and loss of personal property that was contaminated. Facility impacts included a work stoppage, facility contamination, temporary loss of use of some portions of the facilities, and extensive efforts and costs required to assess and mitigate each of these impacts.

2.8.1 Impacts to Personnel

W-1 received a measurable Am-241 intake. About 22 other individuals were also monitored, including W-1's co-workers and family members. All were found to have received no detectable intake.

The current estimate for W-1's dose is approximately 500 millirem Committed Effective Dose Equivalent (CEDE). The individual has been evaluated using several dosimetric techniques that allow particular parts of the exposure mechanism to be evaluated. The combination of the techniques allows the determination of the likely method of uptake, inhalation, ingestion, or injection and it provides an indication of the solubility of the material in the body. The results indicate that the primary exposure was through inhalation of airborne material into the lungs. Continued sampling and analysis is necessary before a final dose is assigned.

This level of approximately 500 millirem CEDE is one tenth of the Federal limit for occupational radiation exposure for one year (5,000 millirem Total Effective Dose Equivalent). Exposure to radiation is assumed to result in a proportional increase in the individuals' long-term cancer risk, although this has not been proven at low doses. Based on the dose projected in this case, the increased risk is likely to be very small or negligible compared to the normal cancer incidence rates.

W-1 also had external contamination from this event. Due to the long delay between the incident and its discovery, it is impossible to know with certainty what his original level of contamination may have been. However, based on the levels of contamination identified on items that were handled by W-1, such as the glovebox door handle (600,000 dpm/100-cm^2) and the MASS inventory sheet provided to NMC-1 (1,000,000 dpm/100-cm^2), the individual likely had contamination levels exceeding 2,000,000 dpm on his hands. When surveyed on July 25, contamination of up to 9,000 dpm was discovered on his thumb. Subsequent measurements also identified lower levels of contamination on other areas of his body, apparently from contact with his contaminated clothing.

Although some contamination was found at the home of NMC-1 and in W-2's vehicle, the impacts to personal property were essentially limited to W-1 and his family. Most of the contamination was removed, but some items were disposed of as radioactive waste. LANL reimbursed the individuals for any contaminated items that had to be disposed of as radioactive waste.

2.8.2 Impacts to Facility Operations

Impacts on facility operations included both Sigma and PF-4. At PF-4, the glovebox line and associated rooms used to produce the uranium nitride pellets was closed down pending investigation of the incident. At Sigma, rooms R3, R108, J108, and K106 were also closed down due to the presence of contamination and to preserve evidence for the investigation. Also, Sigma was vacated for almost 2 days during the response activities.

The costs of the accident included such things as the resources required to assess impacts of the incident, conduct surveys, collect and analyze samples, deploy augmented RAP Teams, decontaminate impacted facilities and equipment, and reimbursement of personnel for personal items. Costs incurred as of September 30 exceeded $250,000. This amount was not inclusive of all monitoring, analysis, and decontamination expenses. Many expenses have yet to be incurred as the majority of the decontamination work remained to be completed.

What is a 'millirem'?

The millirem is a unit used to measure the ionizing radiation dose delivered to an individual as a result of an exposure. The unit is a derivative of the standard unit of the rem, such that one thousand millirem equal one rem. The rem combines physical and biological factors to provide a unit that equates the health risks from different types of ionizing radiation. When a human is exposed to an external source of radiation, such as an X-ray machine, the radiation dose can be directly measured with special instruments. When radioactive material is incorporated into the body, usually through ingestion or inhalation, the measurement of the radiation dose is more complicated. Health physicists measure the amount of radioactive material in the body and how fast it is being excreted, and with those values they calculate the amount of radiation dose received. The sum of the internal and external doses represents the total radiation dose received by the individual, and the sum is referred to as the Total Effective Dose Equivalent (TEDE).

One aspect of internal exposures is that they may extend over a long period of time. This can occur when the radioactive material in the body has a long radioactive halflife and a very slow excretion rate. For example, the radioactive halflife of Am-241 is 432.7 years and its biological halflife (a measure of the excretion rate) in bone is 80-100 years. This means that the majority of the Am-241 incorporated into the bone will remain there throughout the life of the individual. To account for such long exposure times, the radiation dose is calculated as the total that would accumulate over a 50-year period. This is referred to as the Committed Effective Dose Equivalent (CEDE).

The risks to human health from exposure to ionizing radiation have been estimated by studying people who were exposed to very high levels of radiation, such as Japanese atomic bomb survivors and radiation accident victims. From these studies the risk of cancer has been estimated to increase by about 3% for a 100,000 millirem dose. For much smaller doses it is difficult to directly identify the health impacts to the exposed individual. This is mainly due to the difficulty in identifying very small variations from the background cancer incidence rate, and the inability to directly identify the specific cause of individual cancers. Lacking specific data at low doses, health physicists assume that the effect is directly proportional to the dose. Applying this assumption to the 500 millirem CEDE dose would indicate that the risk of cancer to the exposed individual could increase by 0.015% over the natural cancer fatality rate of approximately 25%. For comparison, the average background dose for residents in the United States is about 300 millirem per year, which equals 15,000 millirem over a 50-year period. Note that the background radiation levels can vary greatly; in some parts of the world, such as Kerala, India, and Ramsar, Iran, the background doses can be as high as 30,000 millirem per year.

2.9 Accident Reconstruction

The Board's first and primary responsibility in investigating this accident was to fully understand the nature and progression of the accident itself. In other words, it needed to determine what really happened. In order to do this, the Board postulated that three basic conditions must exist for such an event to occur. First, there must be a source of loose, respirable contamination available for dispersal. Second, there must be a breach in the containment of that material to allow it to escape. Third, there must be a mechanism for the released material to be transported to the environment. While these conditions may seem simplistic and obvious at first, evaluating each separately provides significant insight into the origin of this accident.

The Source Term

During the initial discovery phase of this accident, it was clear to RCTS-1 that the contamination was not of a nature that was normally encountered in the facility. First, the ratio between the alpha particle emission rate and the beta particle emission rate was much different than that expected for uranium, which was the material normally used in the facility, and what was expected in the components that had been received. RCTS-1 immediately requested an isotopic analysis of a swipe sample to ascertain what the contaminant actually was. The results of that analysis showed that the contaminant was Am-241, at least to the accuracy available in the initial test. This isotope was totally unexpected. Second, the contaminant exhibited an unusual behavior in that once it escaped containment, it appeared to quickly adhere to whatever surfaces it came in contact with. It was only spread beyond R3 by direct transfer from W-1's contaminated hands and clothing and by the direct handling of contaminated articles. As a result, the probability of resuspension of the material into the local atmosphere, and the quantity available for subsequent redistribution through secondary contact was very low. While this second condition helped limit the ultimate spread of the contamination, it also compounded the difficulty of detecting and cleaning contaminated objects.

One point of minor confusion was that the results of LANL's isotopic analysis and the initial results of the analyses being conducted at Bettis did not agree on the isotopic composition of the contaminant. LANL's initial measurements suggested that the material was all Am-241; Bettis concluded that the contaminant was mostly Am-241 with a smaller fraction (by activity) of plutonium-239 (Pu-239). Therefore, there was a lingering concern that there could have been multiple contamination events involved in the accident, but the issue did not appear to impair the LANL response in any meaningful manner.

The Board directed LANL to enter R3 and conduct a comprehensive evaluation of the contamination in the room and remove the bagged trashcan and the Swageloks® for evaluation. During evaluation of the room and before the Swageloks® were removed, a large number of swipes were taken for analysis. After the Swageloks® and trashcan had been properly removed from R3, they were to be transported to PF-4 for further evaluation, if necessary, and ultimate disposition. In order to prepare the shipping documentation, the bags containing the trashcan, swipes, and Swageloks® were each analyzed with a portable gamma spectrometer to determine the total radioactive contents. The results are listed in Table 2.9-1.

There is likely to be some uncertainty in these numbers because there is a potential for self-shielding of the low energy gamma emission of Am-241 by the contents of the bags. The U-235 content of the Swageloks® is evident, but the measured value is below the expected value (about 3.4 g) because the fuel pellets are inside the Swageloks®, and therefore are shielded by them. Since the Am-241 contamination is on the exterior of the Swageloks®, the effect of the shielding is much lower. However, the Board believes that the Am-241 values are reasonable estimates because, as will be seen, they demonstrate a good degree of consistency with other related measurements. Also, it should be noted that while there is no plutonium detected, that is not evidence of its absence. It is likely that the plutonium signal would be overwhelmed by the Am-241 signal in these measurements (given equal masses, the activity of Pu-239 is less than 2% of the activity of Am-241).

The total amount of Am-241 from these measurements is estimated to be 3.8 millicuries. Note that the measurements indicate about 62% of the total contaminant is in the packing bags. Assuming that the bag and the Swageloks® were originally contaminated to similar levels per unit area since the bag was also handled in G138, the Board estimated that the level of contamination on the Swageloks® at the point of origin averaged approximately 7 x 10^8 dpm/100-cm^2. The Board also believes that the contaminant, at the

Table 2.9-1 Results of the Portable Gamma Spectrometer Analysis

Item Analyzed	Results
Trashcan containing packing bags	2.36 millicuries Am-241 (0.69g)
Bags of Smears	0.011 millicuries Am-241 (0.0032 mg)
Bag with Swageloks®	1.45 millicuries Am-241 (0.42 mg) 0.00097 millicuries U-235 (0.45 g)

point of origin, was very easily transferable, unlike how it behaved after escaping the containment of the inert glovebox in Sigma.

The Board also directed that LANL attempt to take swipes of the individual Swageloks® in order to estimate the removable fraction of the contaminant. The results indicated that the estimated total amount of removable material on the parts was 0.123 millicuries, about 8.5% of the total measured above. That equates to an average of 0.013 millicuries per part, or approximately 6.3 x 10^7 dpm/100cm^2. The distribution among the parts was fairly uniform, which would be expected after they had been contained together in the bag for transport.

By the time the Board began its investigation, LANL had determined that the Swagelok® containers had been assembled by NMT-11 in the same glovebox line used to fabricate fuel pellets that were a combination of americium and plutonium nitride (referred to as "actinide pellets") for another program. However, most of the powdered americium work was conducted in a different glovebox than where the Swageloks® were assembled, so significant americium contamination was not anticipated in G138. Note that based on process knowledge and experience, NMT-11 fully expected that the exterior of the Swageloks® would be contaminated when they were removed from G138, they just did not anticipate that americium would be dominant, nor that the contamination levels would be as high as what was actually observed.

During the investigation, the Board and NMT-11 continued to consider the actual origin of the contaminant in glovebox G138. NMT-11 had recreated the timeline of the production of the pellets and their assembly into the Swageloks®. In the normal sequence of production for either the uranium nitride pellets or the actinide pellets, most, if not all, of the work with powders is conducted in other gloveboxes. By the time the material is introduced into G138, the material has been pressed into pellets. Also, between individual campaigns NMT-11 performs a "housecleaning" of the glovebox line, which included removing unnecessary equipment and wiping down the glovebox surfaces with cleaning solution and cheesecloth. The intent was not to fully decontaminate the box, but to reduce the amount of loose debris and contamination to minimize impact on product quality.

The main operation performed in G138 is to bake the pellets in a sintering furnace. NMT-11 noted that during the baking of the actinide pellets in the sintering furnace, they have found that a significant fraction, as much as 20-30%, of the americium is volatilized from the pellets and plates out on surfaces inside the furnace. The furnace is mounted such that it forms a well in the floor of G138, and the furnace lid is lifted off the furnace in order to remove the pellets (see Exhibits 2.9-1 and 2.9-2). NMT-11 informed the Board that the work area in G138 where the Swageloks® were loaded with the uranium pellets was right next to, and downstream in the ventilation flow path from, the furnace.

With the assistance of NMT-11, the Board developed a timeline of the work conducted in G138 leading up to the loading of the uranium nitride pellets into the Swageloks® and their removal from the glovebox. The uranium pellets that were ultimately shipped to Sigma

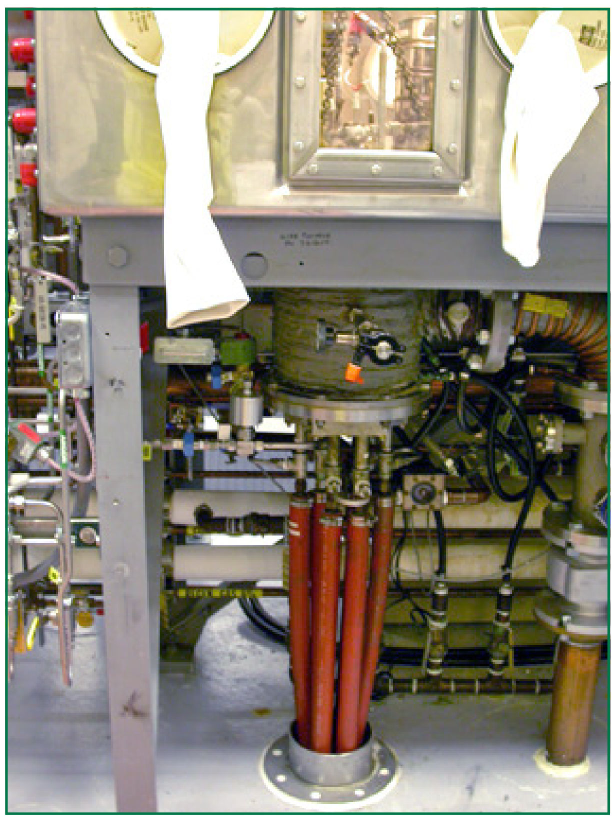


Exhibit 2.9-1 An exterior view of the furnace in the floor of glovebox G138 in PF-4.

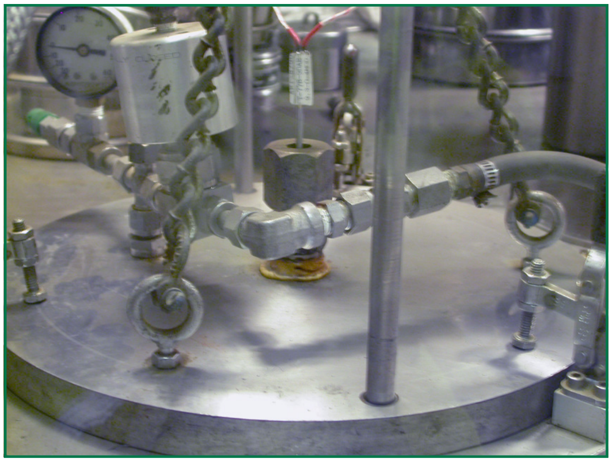


Exhibit 2.9-2 The lid of the furnace in the floor of G138, viewed through the glovebox window.

were from a batch designated as "run 7D" by NMT-11. Table 2.9-2 shows the progression of events associated with those pellets, based on project documentation.

As shown, the records demonstrate that there were two runs of the Pu-239/Am-241 actinide material in the furnace in G138 between the time that the glovebox housecleaning occurred and the time the Swageloks® were handled and loaded in G138. Given the activities and the high fraction of Am-241 volatilized in the furnace, loose contamination would be expected to increase significantly in G138 above the residual levels remaining after the housecleaning of the week of June 13. Since the Swageloks® were loaded in the workspace right next to the furnace opening, and they would be handled with the same gloves used for the furnace work, the probability of the Swageloks® becoming significantly contaminated would be very high.

On July 27, after notification of the discovery of the contamination at Sigma, NMT-11 conducted a small survey in the PF-4 gloveboxes where the pellet processing work had taken place. The sampling in G138 showed contamination levels of 800 milligram/100-cm^2 for all plutonium isotopes combined, and 3 milligrams/100-cm^2 for Am-241. The plutonium contamination levels in the glovebox were elevated due to a plutonium powder sieving operation that had just taken place after the Swageloks® were loaded and removed, and before the samples were taken. The NMT-11 evaluation of the results showed that the Am-241 results were 30% higher than that expected for the amount of Am-241 due to the decay of the Pu-241 isotope of the plutonium as the material aged. Therefore, if one assumes that the 30% difference is due to Am-241 contamination that was already in the glovebox before the plutonium sieving operation was conducted, one can estimate the amount of Am-241 contamination prior to the sieving operations. The result of this assumption suggests that the Am-241 contamination level in the glovebox before the sieving operation was on the order of 0.7 milligram/100-cm^2, which is about 2.3 millicuries/100-cm^2. The records suggest that there was one furnace run after the Swageloks® were removed, so if one assumes that the

Table 2.9-2 Progression of Events Associated with the Uranium Nitride Pellets Shipped to Sigma

Activity	Date	Notes
Uranium pellet run 7D processed	Month of May 2005	Last run of campaign
Glovebox housecleaning	Week of June 13	U pellets in G137
Onset of actinide pellet campaign	Week of June 20	
Swageloks® staged in G139 in bag	Week of June 20	
Actinide pellet 'solutionization' furnace run	Week of June 20	Furnace in G138
Actinide pellet 'reduction' furnace run	Week of June 27	Furnace in G138
18 U pellets selected for experiment	June 28	U pellets in G137
18 U pellets moved to G138	July 6	
Swageloks® moved to G138	July 7	
Swageloks® loaded and removed from G138	July 7	Bagged out in X110
Swageloks® loaded in Hagen can and stored	July 7	Put in safe in room 127

contribution to the contamination was equal for each of the three furnace runs conducted since the housecleaning, then the Am-241 contamination level in the glovebox at the time the Swageloks® were loaded can be estimated to be on the order of 1.5 millicuries/ 100-cm^2, or 3.4 x 10^9 dpm/100-cm^2. This value compares very well with the value of 7 x 10^8 dpm/ 100-cm^2 that the Board estimated to be on the Swageloks® when they were sampled in R3, as described earlier.

Fortuitously, NMT-11 reported that when the room and glovebox were secured for this investigation, they had just completed another run in the furnace with actinide pellets, but the furnace had not been opened yet. Based on this information and NMT-11's recommendation, the Board directed NMT-11 to conduct a series of activities within G138 in the following sequence: (1) take swipes of the current contamination levels in the glovebox; (2) perform a normal housecleaning in the glovebox; (3) take a second set of swipes at the same locations as the first; (4) open the furnace and remove the pellets as normally done; and (4) take a third set of swipes, again at the same locations as before. The results of this activity were not fully conclusive. While the results of the surveys indicated a reduction in total activity when housecleaning was performed and an increase in total activity after furnace operations, the amount of total activity present after furnace operations was less than expected. However, the total activity present inside the glovebox after furnace operations would be sufficient to contaminate the Swageloks® at the values observed from the surveillance activities in Sigma.

The Board also considered the information regarding the baking of the actinide pellets in G138 as to what the implications are for the behavior of the contaminant. From the survey information and the evaluations conducted on the Swageloks® in R3, it appeared to the Board that the contaminant was likely to be very finely divided and powdery while it was in the inert atmosphere of the gloveboxes. The Board also noted that the Swageloks® and the innermost bag that contained them had been sealed within G138 with the intent of maintaining an inert atmosphere for the parts during transfer to Sigma, so the contaminant would continue to maintain the same characteristics in the R3 glovebox. This material would be expected to be highly dispersible and easily resuspended and inhaled.

Through interviews, the Board determined the normal practice for introducing and removing articles from the laser-welding glovebox in R3. The antechamber on the side of the glovebox is a double-doored space that can be evacuated with a vacuum pump and then backfilled with an inert gas. One door is on the exterior of the antechamber—referred to as the "outer door"—and the other door separates the antechamber from the glovebox interior—the "inner door." When an article is to be introduced into the glovebox, the outer door is opened, the article is placed in the antechamber, and the outer door is closed. The ambient atmosphere in the antechamber is then evacuated and replaced with the inert gas used in the glovebox (this may be repeated if necessary to ensure adequate gas exchange). This allowed the operator to maintain the purity of the internal atmosphere of the glovebox. The inner door is then opened, the article is moved into the glovebox, and the inner door is then closed. When articles are to be removed from the glovebox, the operator simply opens the inner door, places the article in the antechamber, closes the inner door, and opens the outer door to remove the article. This allows the small amount of inert atmosphere in the antechamber to escape into the ambient atmosphere of the room. Since this small quantity of inert gas represented no hazard to the operator, and since the potential for airborne radioactive contamination was not anticipated, there was no recognized need to purge and filter the gas before opening the outer door. That 'puff' of inert gas into the room would have carried with it airborne contamination that the operator likely inhaled, but it appeared that after that initial release into the ambient atmosphere of the room, the contaminant quickly began to adhere to whatever surfaces it came in contact with. A similar effect would happen with any contaminated article removed from the glovebox, in that once exposed to the ambient atmosphere of the room, the contaminant would become much less likely to be transferred from the surfaces that it was residing on.

The contamination on the Swageloks® themselves was also consistent with these observations. After removal from the glovebox for swiping (which exposed the parts to the ambient atmosphere), the Swageloks® exhibited an average of 8.5% removable fraction, compared to the apparently high removable fraction that resulted in most of the contaminant remaining in the innermost bag after the parts were removed.

The Board discussed the behavior of the contaminant with a chemist familiar with actinide chemistry. He suggested that the material was likely to be very anhydrous—without water—given its creation in a dry, inert atmosphere, and that upon exposure to moist ambient air it was likely to rapidly absorb water vapor from the air or whatever surface it was resting on. This would result in the contaminant becoming sticky and adhering to whatever surface it came in contact with, which is consistent with all of the above observations.

The Board also directed that LANL, when taking the various swipes, submit some of them for isotopic analysis. The results of these analyses demonstrated that Am-241 was the dominant isotope, and there was a small amount of Pu-239 present. A statistical difference between the LANL and Bettis measurements could not be demonstrated.

The Containment Breach

The mechanism for the initial breach of containment was clearly the intentional opening of the innermost bag and removal of the parts from the bag within the glovebox in R3. Subsequently, the removal of the contaminated bags and tools from the glovebox through the antechamber provided the pathway to the ambient environment. The further openings of the antechamber and the removal of other contaminated articles, which occurred multiple times over the following week, would have brought additional contamination out into the room. That additional contamination was probably at lower levels than the initial release, because the work did not involve direct contact with the highest contaminated surfaces, the parts themselves. However, the gloves and other surfaces in the glovebox would have been contaminated, and so cross-contamination would be likely for anything inside the glovebox.

In testimony, W-1 stated that the potential for significant contamination had never been discussed during planning meetings with NMT-11. He reasoned that the only contamination that he might encounter would be from the uranium in the pellets, and that would likely be only when he opened the Swageloks®. Therefore, he used no personal protective equipment when working in the glovebox. Consequently, when he handled the contaminated bags, tools, and other parts that were removed from the glovebox, it was with his bare hands. Therefore, his hands would likely be highly contaminated. Also, W-1 stated that after he had initially opened the bags, he had been concerned about contamination, so he had gone to a frisker in room R108 and conducted a frisk. According to W-1, that frisk showed no contamination on his hands. After the discovery of the contamination, W-1 stated that he believed that this frisk had failed to detect the contamination because his hands were sweaty and that may have masked the contamination from the instrument.

The Board considered this testimony. It also considered the fact that NMC-1 had detected contamination on her hands on July 14, but she had washed it off and failed to report the incident to the RCTs. Therefore, the Board confiscated both instruments, and directed LANL to test them with an Am-241 source. Both instruments responded to the Am-241 source, and alarmed at appropriate levels. The LANL testing concluded that the counting efficiencies for Am-241 were consistent with the instruments' intended and calibrated efficiencies. Note that LANL had, during the initial surveys, discovered low levels of contamination on the handle of the frisker that W-1 claimed to have used in R108.

The Board also noted that there is a utility sink in R3 near the exit (see Exhibit 2.9-3). The initial LANL surveys had detected high levels of contamination in the sink, on the faucets and on the paper towel dispenser, and spots were found on the floor under the towel dispenser. As a follow-up, LANL had located and surveyed all mops and other cleaning equipment in the facility, but found none that were contaminated. LANL had also determined that the janitor normally responsible for that area had been on vacation during the period of the event, so it was unlikely that the room had been cleaned or the floors mopped between the accident on July 14 and its discovery on July 25. The Board questioned W-1 regarding this observation, but W-1 could not recall having washed his hands in the sink at any time during this period. However, interviews with other staff indicated that it was normal for workers in the room to wash in that sink.

Exhibit 2.9-3 The utility sink found to be contaminated in R3. The drinking fountain was not contaminated.

Transport Mechanisms

As noted above, the initial release of contamination from the glovebox was into the immediately surrounding environment of room R3. After that initial release, the contamination was subsequently transported to other locations outside R3 via a variety of mechanisms.

Most of these mechanisms are apparent from the descriptions contained in Sections 2.3 and 2.4. After the initial opening of the package on July 14, W-1 delivered a piece of paper with the serial number of the parts to NMC-1, and that paper was later found to be highly contaminated. NMC1's hand contamination resulted from contact with this paper, which would also explain the low level of contamination found in the sink at NMC-1's home.

Since W-1 left on the trip to Kansas with his spouse the next day and contamination was found in the spouse's vehicle and personal effects and at the relative's house and the hotel in Kansas, it was obvious that W-1 was significantly contaminated when he left work on July 14. The LANL evaluation of the contamination discovered at those locations indicated that the dispersal of this contamination was through direct contact with W-1's contaminated clothing and hands. There was no indication of tertiary transfer of contamination to other locations after the initial deposition by W-1, nor was there indication of resuspension of the contamination in the atmosphere after deposition. Bioassays conducted by LANL confirmed that W-1's family members had received no detectable intake from their exposures to this contamination.

After opening the bag in the glovebox and confirming the serial numbers of the parts on July 14, W-1 reported that he had gone to his office for a short period and then left the facility for the week. Therefore, the spread of contamination within the facility at this time was likely limited to R3, R108 (the location of the frisker that W-1 used), and W-1's and NMC-1's offices. During the following week, W-1 worked on other parts in the laser-welding glovebox. After removing those parts from the glovebox, W-1 transported them into other areas of Sigma for further work; the bulk of that work was done in room R108. Those parts and W-1's hands and clothing would be contaminated; this would account for the broader spread of contamination into R108 and other offices and work areas within Sigma. Also during this week, W-1 completed preparation of the weld coupons that were to be shipped to Bettis, and he provided them to W-2 for shipment. This handling would account for the contamination found on the package shipped to Bettis and that found in W-2's POV. Consistent with other observations, there was no indication of significant tertiary transfer of contamination to other locations after the initial deposition by W-1, nor was there indication of resuspension of the contamination in the atmosphere after deposition.

Throughout this whole period, W-1 would have been accessing his office in Sigma and going home for the evenings. This would result in the widespread levels of contamination on articles and surfaces at both of those locations. As noted in Section 2.6, LANL spent a significant amount of time attempting to retrace W-1's whereabouts and activities for the period between July 14 and July 25. They conducted extensive surveys to evaluate the extent of the spread of the contamination.

In testimony, W-1 stated that on July 14, when he removed the packing bags from the glovebox, he placed them on the optical table behind where he was standing at the glovebox. He also indicated that he placed the tool used to open the bags into the sheath on his belt, and he continued to carry and use it for the following week. Both of these statements are consistent with physical evidence. The tool and sheath were heavily contaminated when the event was discovered, and surveys in R3 discovered high levels of contamination in a localized area of the optical table W-1 had mentioned. Since the packing bags were ultimately discovered in the sanitary trashcan, it is apparent that at some time W-1 attempted to dispose of the bags. W-1 could not recall when he may have done this, but agreed that it is likely that he did it some time during the week of July 18. Fortuitously, the janitorial staff had not yet collected the trash from the room when the accident was discovered.

During the investigation, the Board attempted to account for all of the parts that W-1 may have worked on in the glovebox. According to W-1's testimony and his logbook, he had prepared four weld coupons and removed them from the glovebox before introducing the Swageloks® on July 14. Two of those coupons were shipped to Bettis, and, under the Board's direction, LANL was able to find the other two coupons within W-1's office. Both of those coupons and the box containing them were contaminated. W-1 had also prepared four weld samples in the glovebox during the week of July 18; those samples had been moved to R108 for further work. LANL personnel believed that they had found those samples and disposed of them in a radioactive waste drum during their decontamination of R108. Although the waste drum was still in the area, the Board chose not to have the drum reopened, and therefore did not verify that the samples had actually been found.

Summary

Based on the evidence, document reviews, and interviews, the Board established the following sequence of events for the progression of this accident.

1. During May 2005 the uranium nitride pellets were fabricated by NMT-11 in a glovebox line in PF-4. This was the last run of the uranium nitride pellet production campaign. The glovebox line was also used to fabricate actinide fuel pellets, a mixture of Pu-239 and Am-241.

2. After the pellets were fabricated, they were stored within the glovebox line until late June, when the final selection of 18 pellets to be used for the Bettis tests was made. During this time the glovebox line was housecleaned, and then a campaign of actinide pellets was started. Two furnace operations with actinide pellets were conducted in G138 after the housecleaning was completed.

3. On July 7 the pellets and the Swageloks® were moved into G138, and the pellets were loaded and sealed in the Swageloks® in G138 to maintain an inert atmosphere during the transfer to Sigma. During this activity, the Swageloks® were contaminated with residual Am-241/Pu-239 from the recent furnace operations in G138. (Since the specific activity of Am-241 greatly exceeds that of Pu-239, Am-241 was the dominant species identified during isotopic analyses of samples of the contamination.)

4. The Swageloks® were sealed in a plastic bag, placed in a transfer can, and then they were moved via the trolley from G138 to an open-front hood in room 128 for removal from the glovebox line. The exterior of the plastic bag was wiped down to reduce contamination, but no effort was made to decontaminate the Swageloks®. The package was placed in two additional plastic bags; those bags were sealed with tape, surveyed, and declared clean. This package

was then placed in a Hagen can and later loaded into a 30-gallon shipping drum.

5. The shipment was transported to Sigma by SUP-5 on July 14, and received by W-1 and NMC-1. The Sigma RCTs were not notified of the incoming shipment and were not involved. NMC-1 accepted the package from a nuclear material accountability standpoint, and she released the package to W-1. NMC-1 tasked W-1 to confirm the serial numbers on the Swageloks® once the package was opened.

6. W-1 proceeded to move the shipping drum to room R3 in the basement of Sigma, where the laser-welding glovebox was located. W-1 then opened the shipping drum, removed the Hagan can, and transferred the Hagen can into the laser-welding glovebox. W-1 then opened the Hagen can and removed the bags containing the Swageloks®.

7. W-1 realized that he needed a tool for cutting open the bags, so he passed his personal knife into the glovebox, removing the empty Hagen can at the same time to free up space in the glovebox. W-1 then cut through all of the plastic bags and removed the Swageloks®, placing them in a corner of the glovebox near the front window. W-1 then removed the plastic bags and the knife from the glovebox, placing the bags on the optical table behind him and the knife back in its sheath on his belt.

8. W-1 verified the serial numbers on the Swageloks®, and he returned the piece of paper to NMC-1 in her office.

9. W-1 secured his work area, returned to his office momentarily, and then left for a 3-day weekend. It was during this weekend that he traveled with his spouse to Kansas to visit a relative.

10. NMC-1, after accepting the piece of paper from W-1, placed the paper under the plastic blotter on her desk to save it for later, and proceeded to a meeting in another area of Sigma. After that meeting, which was inside a radiologically controlled area, NMC-1 alarmed a hand-and-foot monitor when leaving the area. At the advice of her supervisor, NMC-1 washed her hands and re-monitored, clearing the instrument without further alarm. This incident was not reported to the RCTs.

11. After returning from the weekend, W-1 proceeded to conduct other activities in the laser-welding glovebox and other areas of Sigma during the week of July 18. Although the work did not directly involve the Swageloks®, the handling and removal of other parts transferred additional contamination out of the glovebox, which was then transported to other areas of Sigma, W-1's home, and other locations.

12. During the week of July 18, W-1 handled the weld coupons that had been prepared prior to July 14, in order to get them ready for shipment to Bettis. He then provided two of them to W-2 for transport to the shipping office where they were packaged and shipped.

13. During the week of July 18, W-1 initiated discussions with RCTS-1 to plan the work to be done on the uranium pellets in the laser-welding glovebox. At this time, RCTS-1 was informed that the package had been received at Sigma, but did not know the package had been opened.

14. On Monday, July 25, RCTS-1 went to R3 to place a radioactive material label on the laser-welding glovebox in preparation for the work on the pellets. At that time, she discovered that the package had already been opened, and she proceeded to conduct some initial surveys, thus discovering the contamination.

The Board concluded that since W-1 did not anticipate any significant contamination, all of his activities in and around the laser-welding glovebox during the period of from July 14 to July 25 were conducted with no radiological controls in place. Consequently, the Board concluded that the **direct cause** of this accident was the repeated handling of highly contaminated components with no radiological controls in place.

Besides the direct cause, the Board was able to make the following determinations from the information discussed in this section.

When the Board began its investigation it was informed that there had been some question as to whether W-1 had opened the innermost bag within the glovebox or whether he had opened it in the room and then passed the Swageloks® into the glovebox. W-1 stated that he believed he had opened the bag inside the glovebox, but could not recall for sure because of the amount of time between when he had done the work and when this investigation began. The Board concluded that W-1 must have opened the bags inside the glovebox, because the estimated level of contamination on the Swageloks® is much higher than that found anywhere outside the glovebox, and the Board would expect much greater levels to be present in the room otherwise. The highest levels of contamination in the room are on the table where W-1 placed the bags after removing them from the glovebox; those levels are about 3000 times lower than that estimated to be originally available in the package.

The Board concluded that it was the removal of the packing bags and tools out of the glovebox on July 14 that was the initial release of the contamination into the building area. It was this material that contaminated the piece of paper given to NMC-1. It was transferred offsite to the homes of NMC-1, W-1, and W-1's spouse in Colorado and relative in Kansas. The Board also determined that on the week of July 18, W-1 had performed additional work in the glovebox, had removed welding samples from the glovebox, and had worked with those samples in R108 and other areas of Sigma. Therefore, the Board concluded that these activities had released additional contamination from the glovebox, and this material represented the majority of the contamination in R108.

The Board concluded that the behavior of the contaminant after release into the facility most likely was due to the anhydrous nature of the material after it was baked in a high temperature furnace in an inert atmosphere. The Board concluded that this behavior significantly limited the potential for inhalation by W-1, and it also limited the subsequent spread of the contamination to only those surfaces that W-1 touched or came in direct contact with. Finally, the Board concluded that, given the large quantity of contaminant available for dispersal, this fortuitous situation was the only barrier against a much more significant radiation exposure for W-1 and a higher level of risk to the other occupants of Sigma and W-1's family.

The Board concluded that there was sufficient reason to believe that all contamination resulted from a single originating event, and the differences in isotopic mix between samples at Bettis and LANL were due to the difficulty of detecting and quantifying a minor constituent in the presence of a much stronger source.

The Board concluded that the contamination instrumentation in Sigma would detect and respond to the Am-241 radiation emissions, even though that was not their intended application. Furthermore, the Board concluded that W-1's hands would likely have been highly contaminated after handling the packing bags during their removal from the glovebox, as demonstrated by the large amount of contamination on the paper W-1 gave to NMC-1.

The Board could not resolve the fact that W-1 claimed that he frisked in R108 and did not detect any contamination. While sweat can sometimes mask low levels of alpha contamination from detection, the Board believed that to be unlikely in this case. Given the length of time between July 14 and this investigation, it is possible that W-1 may have forgotten the exact sequence of events. In early interviews with the LANL incident investigators before this investigation began, W-1 stated that he had gone to R108 to get a magnifying glass, and that he had needed to frisk in order to get out of R108. W-1 did not mention the need for retrieving a magnifying glass during interviews with this Board. Therefore, the Board believed that he might have actually gone to R108 before removing the bags and becoming contaminated. The Board noted that contamination was found on the probe handle of the frisker in question, but recalled that W-1 had stated that he had used that frisker again during the week of July 18 (W-1 stated that at that time the frisker had indicated slightly elevated levels but did not alarm, so he took no action). Therefore, the Board could not accept the contamination discovered on the probe handle as evidence that W-1 had indeed used the frisker on July 14. Furthermore, the Board could not resolve the mechanism for the contamination of the mop sink, although the Board believed it is likely that W-1 used the sink at some time during the period in question. Therefore, the Board concluded that either (1) W-1 did in fact not frisk after removing the bags from the glovebox; (2) that his frisking technique was inadequate and ineffective; or (3) that he had in fact detected contamination and decided to wash and not report it, as NMC-1 had done. The Board noted that the third alternative would also explain the contamination in the sink, but the Board did not consider the evidence sufficient to draw any firm conclusion since there was ample opportunity for the sink to become contaminated in the intervening period before the accident was discovered.

During interviews, the Board asked all individuals what they believed the appropriate response was to an alarm on a frisker. Several of the workers provided answers consistent with NMC-1's behavior, which is to say that it was acceptable to wash, frisk again, and take no further action if the frisker did not re-alarm. However, all of the HSR-1 staff indicated that the expected response was to remain at the frisker station, control the contamination with gloves or booties, and to immediately contact the RCTs. This second answer was also the response provided in the LANL Radiation Worker training that all of these workers would have received. However, the Board noted that alarm response instructions were not provided at any of the frisker stations that the Board inspected within the facility. The Board concluded that, contrary to LANL expectations, it was an ***accepted practice*** for workers to wash hands and retest if they alarmed a frisker.

The Board concluded that there is sufficient reason to believe that all of the materials that had been removed from the laser-welding glovebox during the period of the accident have been accounted for and placed under appropriate radiological controls.

3.0 Accident Facts and Analysis

In this section, the Board identifies and analyzes the facts collected during the investigation to understand why this accident took place. This section is divided into functional areas to allow a focused evaluation of the various institutional and facility-specific processes that played a role in the event. Since the accident involved multiple facilities and organizations, these functional areas will often be subdivided to address the separate entities.

The goal of this section is to identify any weaknesses in the various functional areas and draw conclusions about how those weaknesses may have contributed to the accident. Weaknesses that may be identified but are deemed to have not played any role in the event are normally not discussed. If the Board believes that these issues warrant further evaluation, they may be passed to the appointing official separately. The conclusions of this section are then cross-linked with the results of the causal factors, barrier, and change analyses to provide an understanding of why the identified causal factors existed.

Before proceeding to the following sections, it is important to discuss the terminology developed by the Board for this evaluation. The Board encountered multiple examples of certain styles of behavior and other characteristics that could be grouped into common categories. The Board has attempted to distinguish these categories when encountered in the analyses by defining the following terms:

- ***Accepted practices*** are behaviors, attitudes, or actions that have become established and engrained in the workers and managers even though the practice is contrary to or outside of the intent of institutional policies and procedures. These behaviors, attitudes, or actions become accepted practices for the workers and managers when the institution has neglected to or been unsuccessful in correcting the behavior and the practices are allowed to persist. The Board considers a practice to be accepted by workers and managers when the Board has identified multiple examples of the same practice either through documentary evidence or through multiple interviews, and the Board has validated that the practice is not an established institutional expectation.

- ***Assumed requirements*** are informally established conditions or controls that do not necessarily have a direct basis in the formally established institutional requirements. In some cases, these arise from a misunderstanding of the actual institutional requirement, in other cases they may be due to older versions of requirements that have become engrained in the belief system of the workers and the managers, even after the requirement is changed. Two complications of assumed requirements are that since they are not institutionalized, they cannot be enforced, and they are not consistently communicated, understood, and applied.

- ***Implied assumptions*** are assumptions that are used in planning or making decisions, but have not been explicitly stated or validated. This is most often observed in interactions between groups, or across organizational boundaries, although sometimes they can appear within groups. For example, if group A decides that group B will act in a certain manner, because that is how group A would act under the same condition, then group A has assumed that the manner of action is the same in both groups. If group A does not explicitly state or validate that assumption, then it is an implied assumption. An implied assumption is generally detrimental to safety because it represents conditions that cannot be explicitly validated or controlled.

- ***Isolated non-compliance*** is when a policy or requirement is not adhered to in an individual situation, although the policy or requirement is normally followed. The intent of this definition is to provide an explicit contrast to an accepted practice.

- ***Latent and immediate conditions*** are two forms of conditions that are present at the time of the event. Latent conditions are situations that were pre-existing in the facility or activity for some length of time before the event. The length of time necessary for a condition to become latent is not defined explicitly, but if the Board determined that the condition existed long enough to be detected and corrected before the event occurred, then it is considered to be a latent condition. For example, accepted practices would be considered latent conditions. In contrast, immediate conditions are situations that arose soon before or during the event.

3.1 LANL's Implementation of ISM

LANL issued Implementation Procedure 300, *Integrated Work Management for Work Activities* (IMP 300) in September 2004. IMP 300 established the comprehensive LANL program for conducting work in a manner that protects people, the environment, property, and the security of the nation. The IMP outlined the Integrated Work Management (IWM) process to ensure that all work is governed by the five steps of the Integrated Safety Management (ISM) core functions: 1) define the work; 2) identify and analyze hazards; 3) develop and implement preventive measures and controls; 4) perform work safely, securely, and in an environmentally responsible manner; and 5) provide feedback and strive for continuous improvement. IMP 300 provided a Hazard Grading Matrix to assist in designating work as low, moderate, or high hazard and established IWD criteria based on hazard grading. IMP 300 also allowed the use of standing IWDs for repetitive, moderate hazard work and established training requirements for all parties involved in the IWM process. Implementation milestones called for Responsible Line Managers (RLMs) to determine the hazard grade of existing activities and evaluate the adequacy of existing IWDs by November 1, 2004. Existing High-Hazard/Complex Activities IWDs were to meet IMP 300 requirements by January 31, 2005, and existing Moderate Hazard Activity IWDs were to be completed by May 31, 2005. Training activities for all active workers were also to be completed by May 31, 2005.

On July 16, 2004, the Laboratory Director ordered a Laboratory-wide work suspension in order to ensure that the Laboratory was operating in a safe, secure, and compliant manner to meet its national security obligations. In order for activities to be resumed, the Director issued specific guidance for safety and security reviews, commensurate with the level of hazard associated with the activity to be performed.

Based on the identified level of hazards at Sigma, a Management Self-Assessment (MSA) of MST-6 Risk-Level 2/3 (RL2/3, with RL2 being moderate hazard and RL3 being high hazard) activities was required. The MSA was completed on September 6, 2004, and RL2 work was authorized to resume on September 10, 2004. The Laboratory Resumption Review (LRR) for MST-6 RL3 activities was completed on October 1, 2004, and RL3 work was authorized to resume those activities on October 7, 2004. The MSA and LRR teams identified 8 pre-start findings and a total of 69 post-start findings and "Substantive Observations." Corrective actions were required to be taken for all findings and substantive observations, but only pre-start findings needed to be corrected before the activity could be restarted.

The corrective action plans for the post-start findings were tracked in I-Track, a LANL issues management tracking database. Many of the corrective actions identified during the MST MSA have projected completion dates in 2006 and 2007. (These corrective actions are discussed further in Section 3.8.)

On February 9, 2005, LANL issued IMP 300.2, *Integrated Work Management for Work Activities*, which replaced IMP 300. IMP 300.2 provided additional guidance and assistance in completing the IWM processes. IWDs were the authorization and approval documents for all moderate and high hazard work performed at LANL. Standing IWDs were only allowed for moderate hazard work. All milestones established in the original IMP 300 were carried forward.

3.1.1 Core Function 1: Define the Scope of Work

The primary document governing the work that W-1 intended to accomplish in room R3 was IWD-05-44, *Handling of UN Pellets*. W-1, acting as PIC and welding subject matter expert (SME), developed the IWD on July 21, 2005. Since W-1 was not familiar with the computerized IWD process, another worker entered the IWD into the system. At the time of the event, W-1 had not completed IWM PIC or Worker training as required by IMP 300.2. Although required by IMP 300.2, the expiration date of the IWD was not given. The IWD did not consider the opening of the shipping package as it had, in fact, already been opened by W-1 on July 14, 2005, one week before the IWD was prepared.

The Board pursued the lack of IWD training further with MST, because Sigma personnel believed that they had received the proper training. It was discovered that MST had developed its own Job Hazard Analysis (JHA) software tool for developing the IWDs, and had implemented the tool and trained the MST staff on it prior to IMP 300.2's promulgation. Since the MST tool was consistent with the LANL JHA software tool developed for IMP 300.2, MST requested and was granted a waiver for the training module required by IMP 300.2 for users of the LANL JHA tool. However, confusion arose regarding the intent of the waiver, and MST believed that it waived all of the LANL IWM training requirements, including three modules that were not covered by the waiver. Therefore, the Board believed that the lack of IWD training for W-1 was due to poor communication and coordination by MST Division when they attempted to implement IMP300.2 JHA requirements in a manner different than the institution's implementation. MST's implementation resulted in a failure to comply with the LANL policy.

The Board concluded that even though IMP 300.2 was in effect at the time that W-1 developed IWD-05-44, W-1's training records indicated that the required training for IWD PIC and Worker had not been completed.

The Board concluded that IWD-05-44 was prepared one week after the uranium nitride pellets were opened by W-1, and it was not intended to cover the opening of the shipping package.

The Board concluded that failure to comply with the training requirements of IMP 300.2 was due to an ***implied assumption*** *that MST had been granted a waiver from all of the LANL IWM training.*

On page 5 of IWD-05-44, the first entry in the "Work Task/Step" column was "Remove pellets from sealed container." This step was intended only to remove the pellets from the Swagelok® containers. The work control process for transporting and opening the shipping package was not addressed. Testimony from multiple individuals indicated that it was normal for such shipping packages to be opened without an IWD, although an IWD apparently exists for shipping and receiving packages in another part of Sigma.

The Board concluded that MST-6 did not fully define the scope of work in that it did not identify the onsite receipt and opening of the shipment as steps necessary to accomplish the assigned task.

Furthermore, the Board concluded that the opening of shipping packages without an IWD was an ***accepted practice*** *at Sigma.*

The Board pursued the question of why an IWD was not developed for the opening of the package. During this investigation, LANL employees frequently reminded the Board that all work involving radioactive materials automatically was classified as a moderate-hazard activity and thus required an IWD. However, this was in conflict with the Board's observations that activities such as opening the shipping package were routinely conducted without an IWD. Furthermore, W-1 had originally believed that the work he was to perform, encapsulating the pellets and welding the cans, was a low hazard activity that did not require an IWD. Interviews with multiple workers indicated that it was RCTS-1's insistence that an IWD was necessary because the work involved radioactive material that drove the decision to develop one for the welding activity.

To resolve this conflict, the Board reviewed in detail both the IMP 300.2 requirements and the software tools used to develop the IWDs. Attachment 1 of IMP 300.2 uses the following "Hazard Grading Question" to determine if an activity is a moderate-hazard level:

> "Does the work involve hazards that inherently could cause **moderate** harm, as in
>
> - Injury requiring medical attention or leading to temporary disability,

- Spill or unplanned release to the environment of hazardous materials, or
- Loss or compromise of classified information?

Note: This question and the following one [the high-hazard grading question] may be answered no if engineered controls have been established, thoroughly reviewed, and proven highly reliable in minimizing the risks without active worker involvement (e.g., commercial insulation on electrical wiring)."

The attachment provides examples of moderate-hazard work, including "work with hazardous chemicals, materials, radiation, or biohazards," and "exposure to laser radiation with potential for eye damage as defined in LIR402-400-01.3." The IWD software tools developed for implementing this attachment, both the LANL-wide tool and an in-house program developed by MST follow this methodology closely. If an activity is determined to be moderate-hazard and involves working with radiation, then both tools establish a requirement that a radiation protection SME must review the work, establish appropriate controls, and then concur on the IWD.

The Board then considered the work involved in opening the shipment and conducting the welding. Given that the potential for Am-241 contamination had never been communicated to the Sigma staff, then the only hazard they recognized was from the total of 24 g of uranium in solid form, with a potential for minor levels of uranium contamination on the surfaces of the pellets. Although uranium is radioactive, this small quantity does not represent a hazard that could reasonably be expected to lead to injury requiring medical attention. The opening of the shipment would involve removal of the Hagen can, which had already been established as a robust and LANL-approved container for such material, and inserting the unopened Hagen can into the laser-welding glovebox, which, based on facility operating experience, could be considered as an adequate and acceptable form of engineered control. Therefore, any incidental uranium contamination on the pellets would be totally contained, by either the Hagen can or the glovebox, during all handling activities; there would be no significant potential for a spill or unplanned release to the environment. Since the laser-welding system had already been declared operational, the uranium represented the only new hazard introduced into the system. Consequently, the Board determined that one could logically argue and conclude that no IWD was necessary for either the opening of the package or the welding activity.

The Board concluded that, given the lack of knowledge regarding the potential for Am-241 contamination, a logical application of the IMP 300.2 process could result in a low-hazard grading for both the opening of the shipment and the assembly and laser-welding of the cans inside the glovebox, and therefore an IWD would not be automatically required for either activity.

The Board concluded that, although it is a good practice, the assumption that an IWD is automatically required for work involving radioactive material is an ***assumed requirement*** *that cannot be adequately enforced.*

3.1.2 Core Function 2: Analyze the Hazards

The Board reviewed the MST Facility Safety Plan (FSP) for Sigma (MST-FSP-03-FAC-5042, revision 3, August 19, 2002). Section 8 of the FSP calls for an annual review of the document performed by the MST-OPS group and the tenants in Sigma. The Board could find no evidence of such reviews. The 2004 MST MSA team noted in Substantive Observation 8.05-01 that, "MST Facility Safety Plans *especially Sigma Complex FSP* need to be updated/validated." Note that this issue was identified as a substantive observation and not a finding. The corrective action plan for the MSA calls for the update to be completed by November 30, 2005. The Board also noted that in spite of the fact that lasers such as that used in this laser welding glovebox are used extensively in Sigma, the current FSP makes no mention of laser safety.

The Board concluded that the Sigma FSP is out of date and incomplete.

IWDs were intended to identify activity-specific tasks, determine and evaluate the hazards associated with those tasks, and to establish controls and requirements to be applied during the conduct of the task. According to testimony, W-1 believed that the uranium nitride pellet work was low hazard and did not require an IWD.

RCTS-1 informed W-1 that since all work involving radiological material was automatically defined as moderate hazard, an IWD was required. Accordingly, W-1 graded the hazard for the welding activity as "moderate." The laser welding glovebox in R3, in which the work was to be conducted, was not designed to protect workers from the hazards associated with manipulation of radiological materials. The glovebox was designed to provide a positive-pressure inert atmosphere to facilitate the laser-welding operations. The glovebox was not connected to a filtered exhaust system, but rather had a recirculation system that contained a HEPA filter to collect and control fumes generated during welding operations. The staff believed that the glovebox would be sufficiently protective for incidental levels of uranium contamination, but there is no indication that the glovebox was ever formally analyzed as a radiological containment system. This fact was not uncovered during the hazard evaluation phase of the IWD process.

The Board reviewed the LANL's IWM program, which establishes the IWD requirements to be implemented by each Directorate. As noted above, the IWD is intended to identify activity-specific tasks, determine and evaluate the hazards associated with those tasks, and establish controls and requirements to be applied during the conduct of the task. A large project might involve multiple and significantly different tasks; and, therefore, there would likely be multiple IWDs developed for the full scope of the project. Also, the intent is for each IWD to stand alone to the extent possible so as to provide all the necessary information to the worker within one package. Since the desire is to have the IWD developed within the work group that will ultimately be conducting the work, projects that depend on multiple organizations will likely have totally separate groups developing IWDs for their portion of the overall project. Consequently, the IWD development processes for large projects could result in IWDs that do not share a common understanding of the hazards inherent in the project. Therefore, communications between separate groups working on a common project become key in ensuring a common understanding of the hazards presented by the project. The Board determined that LANL's IWM program does not provide requirements or guidance for ensuring that such cross-organizational communications occur when large projects are divided between groups or facilities.

The Board viewed the relationship between NMT-11 and MST-6 project personnel as comparable to that of primary contractor to subcontractor. NMT-11 served in the capacity of the primary contractor who interacted with the customer to determine project requirements. NMT-11 then selected MST-6 as the entity that possessed the desired welding expertise necessary to accomplish one task of the project. In the primary contractor to subcontractor relationship it would be the responsibility of the primary contractor to ensure that all hazards presented by the work (or the material being worked on) are adequately communicated to subcontractors.

The Board concluded that LANL's IWM program does not ensure that, when projects are divided across organizational boundaries, the IWDs are developed in a manner that ensures that hazards inherent with the project, or introduced by one part of the project, are consistently recognized, communicated, and analyzed by all groups involved.

The Board concluded that the LANL work control system, as currently implemented, does not ensure that work is planned and conducted in a safe, efficient, and effective manner.

During interviews with both NMT-11 and MST-6 staff, including W-1 and NMC-1, it was determined that multiple meetings had taken place between the project participants to discuss the welding work that MST-6 was responsible for. NMT-11 staff stated that NMT-11 had asked MST-6 about whether Sigma could work with the materials within their facility limits, but both parties agreed that the potential for significant contamination on either the Swageloks® or the pellets themselves was never explicitly discussed. Interviews with NMT-11 staff indicated that they fully expected some americium or plutonium contamination on the parts since they were being prepared in a contaminated glovebox, but they assumed that since the work would be done in another glovebox this contamination would not be a concern. Interviews with MST-6 staff and management indicated that although they knew that the parts were being prepared in a glovebox in PF-4, they did not know that the work was being done in a glovebox also used for americium and plutonium work, and they believed that the parts would be decontaminated before they were shipped to Sigma. This belief was never verified, but was only assumed because it was consistent with MST-6's experience when working with other groups in PF-4 on other projects.

The Board concluded that the NMT-11 did not clearly communicate to MST-6 all of the hazards associated with the material being provided to them.

*The Board further concluded that both NMT-11 and MST-6 had made **implied assumptions** regarding the potential for contamination on the parts that were transferred to MST-6; that those **implied assumptions** were in direct conflict with each other; and that neither group had attempted to communicate or verify those assumptions with the other group.*

The Board concluded that the design of the laser-welding glovebox with respect to radiological controls was not addressed in the IWD process.

3.1.3 Core Function 3: Develop and Implement Controls

LANL has utilized the DOE Necessary and Sufficient process to develop a set of Work Smart Standards (WSS) for identifying the environment, safety, and health requirements applicable to the Laboratory. The WSS represent the contractually binding standards that both DOE and the contractor agreed were sufficient to implement DOE's ISM System at the Laboratory. The Board considered the following requirements from Contract W-7405-ENG-36 Appendix G *List of Applicable Directives* germane to this accident:

- Occupational Safety and Health Act, 1970, Public Law 91-596, Sections 4, 5(a)(1), 6, 8.
- 29 CFR 1910, *Occupational Safety and Health Standards*
- DOE O 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees,* Attachment 2, Sections 6, 7, 8, 14, 16, 18, 19, and 20
- DOE O 5480.19, Change 2, *Conduct of Operations Requirements for DOE Facilities*.
- 10 CFR 835, *Occupational Radiation Protection*

LANL has established formalized institutional programs and requirements for working with radiological materials, and MST has assigned safety and health professionals, including radiological control technicians to implement those requirements in Sigma. (The implementation of the radiation protection program at Sigma will be evaluated in Section 3.4.) MST-6 was the line management organization responsible for ensuring that W-1 performed operations in areas under its cognizance in a safe manner.

As noted above, the opening of the shipment was not identified as a task during development of the IWD and, therefore, was never evaluated for hazards. Therefore, no controls were established that were specific to this shipment opening activity. Regardless of this, interviews with NMT, MST, and HSR-1 staff and managers indicated that there were three general controls and requirements in place that were applicable to this operation.

First, before the package was to be shipped from one technical area to another, LANL requires that the shipment be done in accordance with Department of Transportation (DOT) requirements, so that shipping papers and survey forms would need to be completed documenting the radiological status of the material. The intent of these requirements is to satisfy both DOE and DOT requirements for shipping of radioactive material and also to communicate the radiological conditions to the receiving party. The shipping papers must list the isotope(s) and the activity associated with the primary isotopic constituents of the radioactive material. Since the activity of the Am-241 greatly exceeded the activity of the uranium, it was the primary isotopic constituent of the shipment.

Besides the paperwork required for satisfying DOT requirements, the LANL procedures require that radioactive materials be labeled for both primary and secondary hazards, such as contamination, and Health Physics Radioactive Material Survey Tags are required to include information about the presence of contamination on the bare material being shipped. LANL expects that the "bare material" section of these forms describe the actual material to be shipped, which in this case was taken to be the uranium pellets. Since the pellets are by nature radioactive and understood to be contaminated, the applicable sections of the forms were all marked "not applicable". There was no consideration in the forms for evaluating the radiological status of intermediate barriers. Therefore, in this case the primary radiological constituent of the material being shipped, Am-241, was not identified because the Swageloks® were not expected to be surveyed for contamination. HSR procedures also require that contamination levels on items being shipped between LANL facilities be either measured or estimated based on process knowledge, in order to determine the appropriate packaging and shipping methods. This procedure had not been followed. In this case, the shipment would have required different preparations, had the Am-241 contamination been measured.

Even in general terms, there was no other information conveyed in the labels or Health Physics Survey Tag that would inform the recipient of the potential for removable contamination on the material being shipped. Interviews with the staff responsible for completing the labeling and survey tags indicated that this was a routine practice for materials that were assumed to be destined for another facility with gloveboxes and appropriate controls for handling contaminated materials.

The Board concluded that the primary radiological hazard represented by the shipment was not reflected in the Radioactive Material Transfer Form as required by DOT regulations.

The Board further concluded that the failure to implement labeling and tagging requirements resulted in a lack of full disclosure to the recipient of the radiological condition of the material in the shipment.

Furthermore, the Board concluded that the failure to fully comply with LANL's requirements for preparing radiological shipments is an ***accepted practice****.*

Finally, the Board concluded that the belief that the recipient would know that the material being shipped was contaminated and that the material would be handled appropriately was an ***implied assumption*** *that had not been verified.*

A second LANL requirement is that all incoming shipments with radioactive material are to be surveyed by HSR-1 staff within 8 hours of the morning after the arrival of the shipment. This receipt inspection requirement flows directly from 10 CFR 835, and it is intended to ensure that the integrity of the package was not compromised during shipment. This requirement has been carried forward into the Sigma FSP. This requirement does not necessitate the opening of the package for conducting the inspection. Interviews with W-1 and NMC-1 indicated that neither of them had contacted the facility RCTs regarding receipt of the package for completion of the inspection, even though they were both aware of the requirement. Interviews with the RCTs and their supervisors indicated that they were not aware that the package had been received; the only notification they would normally receive is if contacted by NMC-1 or the package's recipient. Consequently the receipt inspection was never completed. The interviews also indicated that the RCTs had previously expressed concerns to NMC-1 that they were not being notified of incoming packages, and they believed that the issue had been addressed. However, those concerns had been handled informally, and no documentation existed of either the concerns or their resolution. As a result, the Board requested documentation for all radioactive shipments that had been received at Sigma since January 2004 and all documents for receipt inspections conducted during that period. The Board received documents for 36 incoming shipments and five receipt inspections. However, the Board could find no correlation between the two sets of documents.

The Board concluded that the receipt of the shipment of the Swagelok® containers at Sigma had not been conducted in accordance with LANL and DOE requirements.

Furthermore, the Board concluded that receipt inspections of radioactive material shipments were not routinely being conducted at Sigma, regardless of LANL and DOE requirements.

The Board concluded that the failure to notify the Sigma RCTs of incoming shipments of radioactive material was an ***accepted practice****.*

A third control that was identified during interviews is an expectation that the Sigma RCTs be present whenever radioactive shipments are opened within the facility. MST-6 and HSR-1 workers and managers uniformly acknowledged this expectation during interviews. Both W-1 and NMC-1 also indicated that they were aware of this expectation, but W-1 did not notify the RCTs that he was opening the package. In addition, during the week of July 18, when W-1 was preparing the IWD for the welding work, RCTS-1 was involved in its review. The Board determined from interviews that during discussions between W-1 and RCTS-1 at that time, W-1 acknowledged to RCTS-1 that the package had already been received, but did not disclose that it had been opened. As a result, RCTS-1 was not aware that the package had been opened until the following Monday, July 25, when she went to R3 to place a radioactive material label on the glovebox in preparation for the work.

The Board pursued this third control further and determined that it was not documented in any of the facility documentation. After reviewing the MST documentation and discussions with MST-6 management and HSR-1 staff, the Board determined that this third control was not a formal requirement and was likely an informal interpretation of the requirement for the receipt inspections discussed above.

The Board concluded that the expectation that an RCT be present when radioactive material shipments are opened at Sigma did not exist as a formal requirement, and, therefore, that it was an ***assumed requirement*** *that could not be adequately enforced.*

The Board concluded that MST did not ensure that controls were adequately developed and implemented for the opening of the shipment of the Swageloks®.

3.1.4 Core Function 4: Perform Work Within Controls

As noted above, the Board determined that there were two formalized requirements and one additional ***assumed requirement*** that were in place in Sigma that established controls for the opening of the radioactive material shipment. The Board determined that those controls were not effectively implemented, such that all were circumvented by the actions of W-1 and NMC-1.

The Board attempted to determine if there were other actions taken on July 14 that could also have provided some degree of control over this activity and whether the work was conducted within those controls. Two related actions were identified and evaluated by the Board.

First, when the package was being prepared for shipment in PF-4, the plastic bags containing the Swageloks® were placed in a Hagen can. For security purposes a TID was placed on the Hagen can. The Hagen can was later placed inside a 30-gallon drum as the final shipping container, and a TID was also placed on the 30-gallon drum. Upon receipt, the NMC-1 logged the shipment into the MASS and turned the shipment over to W-1. As part of the logging of the shipment receipt, NMC-1 should have noted the presence of the TID on the outer drum, but did not explain to W-1 the significance of the TID. W-1 then transported the 30-gallon drum to R3, removed the TID from the drum, removed the Hagen can from the drum, and then removed the TID from the Hagen can. The Board determined that LANL procedures required that two trained and approved personnel were necessary to be present to remove these TIDs. NMC-1 was trained as a TID custodian and was responsible for ensuring that the TID requirements were properly followed. W-1 had never been trained in TID removal, and, therefore, he was not on the approved TID-removal personnel list. Consequently, the removal of the TIDs by W-1 was not conducted in accordance with the LANL requirements. If NMC-1 had been notified that W-1 wanted to remove the TIDs, she would have needed to find another approved person to help remove them. As a consequence, the opening of the package would have received additional attention.

Second, later on July 14, NMC-1 alarmed a hand-and-foot monitor in another area of Sigma after handling the contaminated paper provided by W-1. However, NMC-1 did not respond to that alarm in accordance with the established requirements and LANL radiation worker training. Those requirements would have been to stay at the monitor, notify the RCTs, and await their response. Rather, at the advice of NMC-1's supervisor, she washed her hands and retested, clearing the monitor on that try without another alarm. (This was identified above as an ***accepted practice.)*** If NMC-1 had notified the RCTs at that time, it is likely that the contamination event would have been detected on the first day.

The Board concluded that regardless of MST's failure to adequately evaluate the activities involving the opening of the shipment, there were multiple controls in place that could have *prevented the accident or mitigated the impacts through early detection of the release.*

However, the Board also concluded that those controls that were in place were not effectively implemented within the facility.

The Board concluded that W-1 failed to follow multiple established controls when opening the Swagelok® shipment.

The Board also concluded that NMC-1 failed to follow established controls in her role in receiving the shipment.

In addition, the Board concluded that both NMC-1 and her supervisor failed to follow established requirements in responding to a contamination alarm.

As a result of multiple compliance failures by multiple personnel, the Board concluded that inadequate adherence to institutional controls is an **accepted practice** *at Sigma.*

3.1.5 Core Function 5: Feedback and Improvement

The core function of feedback and improvement is implemented at multiple levels in a large complex organization such as LANL. In this section, the Board considered the feedback and improvement processes in place at the working level. The formal MST, NMT, HSR, LANL institutional, and LASO oversight processes are evaluated in Section 3.8.

The Board searched the DOE Occurrence Reporting and Processing System (ORPS) database to identify previous events with characteristics similar to the event under investigation. The following reports were identified:

- ALO-LA-LANL-SIGMA-2005-0005, Management Concern: Failure of Formality of Operations results in Red Lock bypassed during removal of a carboy auto alarm system, April 19, 2005
- ALO-LA-LANL-SIGMA-2003-0001, Potential Concern: Radioactive Material Being Used in an Experiment Found in an Uncontrolled Area, August 20, 2003
- ALO-LANL-SIGMA-2001-001, Materials Technology Metallurgy Group (MST-6) Employee Enters Confined Space Without the Required Entry Permit, October 24, 2001

In April 2005, MST-6 facility management placed a subcontractor employee in a potentially compromising condition by instructing the worker to continue the job after the worker expressed a concern about a lockout/tagout on an electrical system. This failure of formality of operations resulted in the bypass of a red lock during removal of an alarm system. The root cause of this incident was that management had insufficient awareness of the impact of its actions on safety. A contributing cause was that communications between working groups was less than adequate.

In July 2003, an RCT found radioactive material under a hood in an area of Sigma that was not posted as a radiological area. The hood was not certified for radiological operations and the material was not labeled as radioactive.

In 2001, an MST-6 worker willfully entered into a confined space area without a permit. This action was directly contrary to the applicable work instructions and, as such, constituted a failure of formality of operations.

In addition, an incident occurred within another room at Sigma during the course of this investigation that also demonstrated characteristics similar to this accident. In that incident, a worker was preparing a work area for a new project by removing old equipment, cleaning the area, and installing new equipment and support utilities. The work being conducted at the time of the incident had not been evaluated using the IWD process. In the course of the work the worker discovered a suspect container of powder in a fume hood; he checked the powder with a survey instrument that happened to be in the room, determined that it was uranium, and then surveyed and tagged it and other equipment that he found to be contaminated. The worker did not notify the Sigma RCTs of the situation. They only discovered the incident several days later. In addition to dealing with this legacy material without RCT involvement, the worker also removed an old press from the fume hood, determined that it was contaminated, labeled it, placed it on a cart, and moved it out of the room. The press was estimated to be four feet tall and weighing about 250 pounds. The worker and a coworker removed the press from the hood by hand without any special tools or safety precautions (ORPS Report NA—LASO-LANL-SIGMA-2005-0012).

The Board concluded that the ORPS reports cited demonstrate a recurring pattern of inadequate implementation of the IWM process and appropriate control procedures by MST-6.

3.1.6 Guiding Principle 2: Clear Roles and Responsibilities

Implementation Procedure (IMP) 300.2 assigned clear roles and responsibilities to Responsible Division Leaders, RLMs, PICs, IWD preparers, and workers. LANL had established multiple modules for teaching the various aspects of the IWD process, including separate classes for workers, IWD preparers, and PICs. However, the Board determined that some of the MST-6 staff, including W-1, had not completed the required IWD training. Regardless, W-1 acted as the preparer, PIC, worker, and welding SME for the IWD that was intended to cover the welding of the uranium pellets into the cans.

The Board concluded that although MST-6 employees involved in this accident believed that they understood their roles and responsibilities for generating and managing IWDs, they had not received required training nor were they fully aware of their responsibilities under IMP 300.2.

One attribute of effective management is to ensure that each employee (or each position) in the organization has an up-to-date job description that defines responsibilities, authorities, and interfaces. The Board requested copies of selected MST-6 employee position descriptions. The response of management was there were few, if any, written position descriptions for MST-6 personnel and managers. As an alternative, MST-6 provided copies of selected Individual Performance Objectives to the Board. A review of those performance agreements indicated that management placed a high priority on mission accomplishment and a low priority on operational safety. The performance agreements motivated employees to accomplish work rather than accomplish work safely.

The Board concluded that MST-6 management has not adequately documented or communicated safety roles, authorities, responsibilities, or interfaces to employees. The Board is concerned that MST-6 management emphasized mission accomplishment to the detriment of safety.

3.1.7 Guiding Principle 3: Competence Commensurate with Responsibilities

IMP 300.2 identifies required IWM training for key participants. Also, the Virtual Training Center contained an Integrated Work Management Training Matrix that specified the required training for preparers, PICs, workers, and others. A review of training records indicated that W-1 was not fully trained in the roles of IWD worker, preparer, and PIC. As an informal and partial compensatory measure, some of the MST-6 staff familiar with the computer program for generating IWDs are normally used to create the final document after receiving the input from the preparer. Another MST-6 employee assisted with the creation of IWD 05-44, so that it was essentially compliant with IWM.

The Board concluded that while W-1 was competent to perform his assigned duties as a welder, he was not fully trained or qualified to perform the role of IWD worker, preparer, or PIC.

The October 2004 MST Division LRR/MSA post-start findings 12/04-4.02-01, 12/04-4.05-01, and 12/04-4.06-01 in citing various training deficiencies concluded: "Inadequate coupling exists between employee training plans and IWD training requirements to effectively assess worker qualification status." As of the date of this report, these findings remain uncorrected.

The Board concluded that MST-6 management did not assure that employees completed training required by IMP 300.2 prior to authorizing work under IWD-05-44.

Furthermore, the Board concluded that since MST-6 management was aware of the inadequate coupling between training plans and the IWD requirements, the authorization of work without adequate training was an ***accepted practice*** *in MST-6.*

Upon receipt of the shipment on July 14, NMC-1 logged the receipt into the MASS and released the shipment over to W-1. W-1 then transported the 30-gallon drum to R3, removed the TID from the drum, removed the Hagen can from the drum, removed the TID from the Hagen can, and placed the Swagelok® package in the laser-welding glovebox. NMC-1 was the responsible custodian for the TID removal process, but did not ensure that W-1 was aware of the procedure for removing TIDs before releasing the shipment to him. Later that day, W-1 opened the plastic bags containing the Swageloks®. Although W-1 was trained as a radiological worker, he failed to obtain assistance from an RCT prior to opening the radiological material shipment. At no time during these activities did W-1 request assistance from RCT-1, RCTS-1, RCT-3, NMC-1, or NMC-2. Consequently, neither the RCTs nor the nuclear material custodians monitored any of these activities. When W-1 returned the paper with the confirmed serial numbers to NMC-1 later that day, it should have been apparent that he had already removed the TIDs and opened the shipment. NMC-1 apparently did not recognize the situation and took no action.

The Board determined that LANL offered a training module for nuclear material handlers that, according to the module's scope, would be required for workers conducting such activities. The Board also determined that this module would provide the training necessary for these activities to be performed within LANL requirements. However, MST-6 had not identified this training as necessary for W-1. Consequently, the only related training that W-1 had received was LANL Radiation Worker training, which does not address such task-specific requirements.

The Board concluded that MST-6 did not ensure that W-1 had the appropriate training necessary to handle nuclear material or remove the TIDs from the shipment.

Furthermore, the Board concluded that NMC-1 did not follow the TID procedure by ensuring that authorized personnel remove the TIDs from the shipment.

3.2 LANL's Response to Onsite Contamination

The discovery of the incident occurred on July 25, when RCTS-1 was preparing to label the laser-welding glovebox and noticed a Health Physics Radiological Material Survey (HPRMS) tag in a garbage can. Realizing that the presence of the tag in the trash indicated the shipment might have been opened, RCTS-1 verified this with W-1 and then conducted a preliminary survey of the work area to determine if any impacts had occurred as a result of this activity. The results indicated total alpha contamination in excess of 600,000 dpm/100-cm^2 and removable alpha contamination in excess of 100,000 dpm/100-cm^2. RCTS-1 also observed that the nature of the contaminant was different from that usually found in Sigma. The immediate actions of RCTS-1 were to notify management, take samples for isotopic identification of the contaminant, request additional radiological support, take nasal smears to check for potential intakes, obtain appropriate instrumentation, and construct makeshift boundaries to delineate and control access to the contaminated areas.

W-1 was surveyed by an RCT, contamination was found on his thumb and clothing, and he was decontaminated. Survey efforts for the balance of the day focused on areas frequented by W-1, including his office, where contamination was located on a number of items. Surveys in other areas near W-1's office did not detect any contamination. When it was recognized that the original contamination event might have occurred on July 14, MST and HSR requested that a DOE RAP team be deployed to the home of W-1 to check for contamination there. The RAP team verified the presence of significant contamination at W-1's home on the evening of July 25.

In the morning of July 26, a critique was conducted to review details of the incident and to continue efforts to identify potential impacts and mitigation requirements. Due to concerns with the possible extent of the contamination, the Deputy Laboratory Director directed that MST, NMT, HSR, EM&R, and LASO form an ad hoc management team to coordinate the response to the event. This team recognized that it was highly probable that contamination had already been spread to other offsite locations besides W-1's home so planning for the offsite and onsite response was split out into separate, but coordinated, efforts. Immediately after the critique, the meeting broke up into two sessions to specifically address onsite and offsite response needs. In the critique, it was decided that employees would be sent home while more definitive surveys were conducted in Sigma to characterize the facility and to provide time for decontamination work to be completed where necessary. Prior to sending personnel home, they were surveyed for contamination. This included a total of some 162 personnel including permanent Sigma staff and temporary workers performing work in the facility. All surveys indicated less than detectable activity. With the facility vacant on July 27, surveys focused on areas that personnel would come in contact with on a regular basis (hallways, office areas, restrooms, etc.). Since it was apparent that most of the contamination had been spread by W-1 through direct contact, most of these surveys were based on an "ergonomic approach" that emphasized the common and most likely objects and locations that W-1 may have handled or visited, such as doorknobs, faucets, chairs, computer keyboards and mice, and documents. Also, higher risk areas such as the facility's floors and common areas were surveyed. The ad hoc management team conducted daily "plan of the day" and "end of the day" meetings to review the current situation and to determine what additional actions would be required to respond to and control both the onsite and offsite impacts. The Deputy Laboratory Director was periodically briefed on the status of the response, and was notified when new issues arose.

On July 28, Sigma personnel were allowed back into the facility. This allowed the management team and the RCTs to interact with the occupants to attempt to discover who may have had contact with W-1 during the period of concern. At this time, NMC-1 recalled that she had accepted the paper from W-1; the paper was retrieved, surveyed, and contamination was detected to levels of 1,000,000 dpm (having been placed under the desk blotter, the paper had not been detected during earlier surveys). At this point, NMC-1's office and vehicle were surveyed and the decision was made to deploy a RAP team to her home, where a small amount of contamination was found in a sink. NMC-1's office was determined to have contamination in various locations, so it was vacated and posted as a contamination area until it could be fully evaluated and decontaminated. Three days later, RCT-2 was sent to room R108 to perform radiological surveys, since W-1 conducted much of his work in this part of the facility. Survey results indicated numerous areas had been contaminated with alpha contamination up to 50,000 dpm/100-cm^2. The Board is concerned that while it was well understood that W-1 conducted several activities in R108, personnel were allowed access to the area in the absence of a thorough characterization of the area. On that same day, HSR-1 management requested that hand and foot monitors be installed at the exits of the facility so that personnel could survey themselves prior to leaving the building. Shortly after the monitors were placed inside the facility, two individuals set off the alarms at values of approximately 1,000 dpm, and Am-241 was identified as the contaminant. The criterion for removal of the monitors was the completion of 3 days with no alarms. This criterion was met approximately a week and a half later and the monitors were removed.

Specific guidelines were established to define conditions that would require the re-evacuation of the Sigma facility. A re-evacuation would be considered if more than 1,000 dpm of contamination was detected on any individual. Immediate evacuation would be required if 10,000 dpm was detected on any individual or if any object was found that met or exceeded 600,000 dpm/100-cm^2. The Board determined that these criteria had no firm technical basis but were selected based on the levels of contamination that had been observed so far within the facility.

At the time that this event occurred, Sigma had no contamination areas posted. The basis for posting contamination areas was 1,000 dpm/100-cm^2 removable alpha contamination (assuming that the contaminant was uranium), and the beta-gamma contamination levels within the facility were not considered. It should be noted that DOE regulations are the basis for these posting requirements; the 1,000 dpm/100-cm^2 removable alpha contamination criteria is appropriate for uranium, but the equivalent value for Am-241 is 20 dpm/100-cm^2. Review of the alpha contamination levels prior to the event indicated only marginal removable levels. Based on pre-event conditions of the facility, the Board was concerned that it should have been recognized that any alpha contamination detected after the event could be attributed to the event, and that LANL should have changed the posting criteria as appropriate. The Board was concerned that the values established for re-evacuation of the facility were technically flawed. The basis of the Board's concern is that the 1,000 dpm contamination criteria on an individual for consideration for re-evacuation is 50 times the value for removable actinide activity and 10 times the average for total actinide activity. Consequently, the 10,000 dpm criteria for immediate re-evacuation was 500 times the removable value and 100 times the value for total actinide contamination. Items found to have 600,000 dpm/100-cm^2 would far exceed the removable contamination surface radioactivity guidelines. As such, it appears that there was no basis for these values when compared to the surface radioactivity guidelines. In addition, the Board is concerned that the facility had not been posted as a Controlled Area in accordance with DOE requirements during this timeframe.

From August 2 through August 5, radiological surveillance activities continued within the Sigma facility. Some incidental contamination was identified that appeared to be consistent with the areas that W-1 had frequented. Based on testimony, the Board determined that the surveillance activities conducted from the point of discovery on July 25 through August 5 had not been formally documented, apparently due to the limited number of qualified RCTs available to accomplish the tasks. On August 5, RCTs directly involved in the survey activities met together to complete the documentation. The Board reviewed the radiological survey documentation and determined that there were several incidences in which the survey information was inadequately completed, technically flawed, and in some cases not sufficient to adequately document the radiological hazards present. For example, limitations in portable instrument capabilities, such as when the instrument's minimum detectable activity level exceeds the posting criteria, were not adequately compensated for by augmenting the results with removable contamination surveys that can achieve lower detection levels. The initial characterization of R108 and, to some extent, room R3 did not evaluate the transferable component of the contamination present. (For further discussion of the LANL radiation protection program, see Section 3.4.). In order to provide continuity and completeness of a radiological surveillance effort, it is imperative that the survey activities are documented in a timely fashion. The Board determined that LANL managers had not reviewed the facility survey documentation to ensure its accuracy and completeness before the Board began its investigation on August 16.

The Board concluded that the ad hoc management team decided to allow personnel to re-occupy the facility before the status of the facility had been fully evaluated and documented.

The Board also concluded that the quality of the survey documentation was inadequate to demonstrate that the building had been fully evaluated. While it is understood that initial surveys of personnel indicated no detectable activity, two separate contamination alarms on hand and foot monitors in the short time period they were installed should have been indicative of a continued uncontrolled condition. In addition, during the time of this investigation isolated areas of contamination and contaminated objects were still being discovered, including one incident that resulted in the skin contamination of a worker.

Shortly after the initial discovery it was recognized that additional RCT support would be necessary to regain radiological control of the facility. Several RCTs from TA-55 and other LANL facilities were deployed to Sigma for support. Based on interviews, the Board determined that this supplemental RCT support was difficult to maintain, complicating the Sigma RCT supervisor's difficulties in managing the building characterization efforts.

The Board concluded that the ad hoc management team and command and control structure established to respond to this accident did not have sufficient resources and processes to adequately manage the necessary efforts. The Board evaluated LANL's Incident Command System and concluded that many of the Board's concerns with the onsite response activities would have been addressed had this system been activated. The activation of the Incident Command System would have provided leadership, formality, decision-making processes, and resources that are designed for, and experienced in, responding to hazardous materials accidents. The Board's understanding is that implementation of the Incident Command System process would also have alleviated many of the difficulties in acquiring and retaining required logistical support such as the RCTs, because of the authority vested in an incident commander during activation.

3.3 NNSA and LANL's Response to Offsite Contamination

Following identification of the extent of the contamination on July 25, MST and HSR immediately became concerned that W-1 may have spread contamination to his home, POV, and other offsite locations he may have visited. Because DOE contractors cannot conduct offsite radiological operations under their own authority, a DOE RAP team deployment was requested to conduct a survey of his home. Significant levels of contamination in the residence were verified the evening of July 25. (In reality, the RAP team was composed of LANL staff, but in such an authorized deployment they are under the direct supervision of DOE management.) Arrangements were made for W-1 to stay in a motel while a decontamination team completed a more thorough survey and decontamination of his home.

On July 26, the ad hoc management team assumed responsibility of the accident response, and a portion of the team focused on the offsite concerns. Following the identification of contamination on office equipment of four other Sigma employees, their homes were also surveyed by RAP to check for possible contamination. Of those four homes, contamination was only found at NMC-1's residence. At that residence, one swipe indicated a removable contamination level of 430 dpm/100-cm^2 on the master bathroom sink. This contamination was subsequently cleaned up.

On July 28, W-1 informed the ad hoc management team that his spouse, who was currently working and residing in Lakewood, Colorado, had come to visit him on July 14 and the two of them had traveled to Great Bend, Kansas, to visit a relative. W-1 was concerned that his spouse and relative's homes could also be contaminated. A RAP team was subsequently deployed to Lakewood on July 29 and from that location to Great Bend on July 30. That RAP team was augmented with LANL staff qualified in decontamination techniques, property management, and radioactive material packaging and shipping so that any contamination discovered could be cleaned up or removed as necessary.

Surveys of the spouse's home and vehicle identified contamination at several locations including a suitcase, a pouch, and in the vehicle to a maximum of 2200 dpm/100-cm^2. All contaminated articles were items that W-1 had handled, and the contamination in the vehicle was where W-1 had sat. There was no evidence that W-1's spouse had either been contaminated or had spread the contamination further by secondary transfer. ("Secondary Transfer" occurs when contamination initially deposited by W-1 is later spread to other locations by subsequent activities.) The contaminated items were decontaminated or packaged for disposal as waste and shipped back to LANL.

The following day, the RAP team conducted surveys of the home of W-1's relative in Great Bend. Contamination was detected on a number of items including two chairs, a car radio, the kitchen range, garage refrigerator, and shop sink. The highest contamination level identified was 2400 dpm/100-cm^2 on the arm of a chair. As with W-1's spouse's home, all contamination could be associated with direct contact with W-1. There was no evidence of secondary transfer. Items were either decontaminated or packaged for disposal as contaminated waste and shipped back to LANL.

While in Great Bend, the RAP Team Leader and RPPM-1 discussed whether to survey the hotel room where W-1 and his spouse had stayed. However, it was felt that the contamination levels were expected to be too low to be a threat to anyone's health, and the activity was likely to attract public and media interest. The RAP Team Leader insisted that it would be best if LASO made the final decision on this question. After discussions with LASO representatives, it was agreed that the limited potential for and negligible risk from contamination did not warrant the potential publicity issues that could result from conducting surveys of the hotel room.

After reviewing the offsite actions taken, NNSA senior line managers at headquarters expressed concern about the decision not to check the hotel room. Therefore, on August 6, a RAP team returned to the hotel to conduct a survey of the room. At that time fixed contamination was detected on the arms of two chairs located in the room. The maximum contamination level detected was 1600 dpm/100-cm^2. Contaminated items were packaged for disposal as contaminated waste and shipped to LANL, and the hotel was compensated for the loss.

On August 10, the RAP team returned to W-1's home, at his request, to check some additional items he felt might have been contaminated. Items checked included a duffel bag containing a pair of coveralls and several hand tools. Contamination was detected on these items as well as on two trash receptacles. The items were all successfully decontaminated or packaged for disposal and returned to LANL.

In directing the offsite response, the ad hoc management team determined when offsite deployments were required and initiated requests for RAP assistance. As per the normal RAP deployment process, approvals were required from the LANL Director, and NNSA Headquarters' Office of Emergency Operations, NA-40. Although a LASO representative indicated that LANL could not deploy without LASO approval, LANL indicated that they believed they could deploy with only the LANL Director and NA-40's approval. While on deployment, the RAP Team Leader and RAP Team Captain operated with relative independence within the pre-identified scope for the deployment. Where additional scope was identified, such as the question concerning the survey of the hotel in Great Bend, additional guidance from LASO and NA-40 was required.

It is the Board's belief that the offsite response adequately addressed potential health and safety concerns. In addition, the Board considered as a good practice the concept of augmenting the RAP teams with other capabilities. The DOE RAP teams are normally only authorized to conduct surveys and evaluate the radiological risks of a situation. In this particular case, LANL and the RAP program management recognized the need to provide a full response and recovery capability to minimize the impact on the affected individuals. Therefore, they augmented the RAP teams with experts in decontamination, waste management, packaging, transportation, and property management. The Board also took note of the compliment paid to the response personnel by W-1, who indicated in interviews that he appreciated the sensitivity displayed by deployed personnel in their interaction with W-1 and his family members.

Although the offsite response was successful, the Board identified several lessons learned to improve preparedness for future incidents.

The Board was informed that LASO had withdrawn from active participation in the RAP program due to safety concerns with the expanded mission since the September 11, 2001, terrorist attacks, lack of training, and lack of personnel resources. While individual staff members' participation in the RAP program is voluntary, DOE Orders require that LASO management maintain some responsibility and processes for handling offsite emergency response requirements in support of LASO operations. These requirements extend from the fairly simple radiological contamination concerns, such as required by this incident, to mitigation of offsite impacts following a major radiological emergency. The Board noted that a support agreement between LASO and the Service Center was drafted in April of 2003 for support and coordination of the LANL/LASO participation in RAP. It is not clear that this agreement was in fact ever signed although one LASO representative indicated that it was canceled long ago. The Board believes that LASO should develop such an agreement with RAP to cover both LANL's participation in the program and to spell out the requirements and resources necessary to support LASO missions at Los Alamos.

Another issue identified was the lack of communications concerning this event with the NNSA Program Secretarial Officer responsible for the LANL site, the Deputy Administrator for Defense Programs, NA-10. During the deployment of the RAP teams, the only NNSA headquarters office involved was NA-40, the organization responsible for the RAP program. While NA-10's office was regularly kept apprised of the situation after the fact, they were not included in the decision-making processes. The LASO refusal to accept responsibility for the offsite response would lead to just such problems. By eliminating or limiting the LASO role in the offsite response, it is easy for the responders to overlook the requirement for keeping NNSA line management involved in the decisions as the event progresses. It should be noted that at the insistence of the RAP program managers, LASO personnel did participate in some of the RAP deployments in addition to their participation in the planning meetings. In fact a LASO representative acted as the RAP team leader for at least two of the deployments.

The Board concluded that LASO failed to adequately address DOE's offsite emergency response requirements. It is the Board's *belief that LASO should complete the support agreement with RAP to define mutual expectations and roles and responsibilities. In any event, LASO needs to define resource requirements for mitigating offsite impacts from normal and emergency operations at LANL. As part of a comprehensive emergency management program, LASO needs to define its role in coordinating overall implementation of command, control, and communication functions.*

The Board concluded that the lines of communication, authority, and responsibility were not adequately defined between LASO, NA-40, and the cognizant Program Secretarial Officer (NA-10) for the command and control of the offsite response activities.

The Board noted that RAP teams deployed during this incident did not always include a Public Information Officer (PIO), based on a recent change in RAP policy. Part of the guidance provided by NA-40 with the policy change was that the RAP teams should coordinate closely with the requesting entity to ensure coverage of media concerns. In making the change to the policy, NA-40 failed to provide clear guidance on the handling of PIO responsibilities when the incident involves a DOE/NNSA site. In this case, DOE/NNSA has the lead in the response and must provide a PIO to coordinate communications at the incident scene. The policy change also ignored the need for PIOs with specific expertise in addressing specific activities or hazards. Lacking a PIO, the Board believes that the RAP teams should be provided with clear guidance on how to respond to media contacts and other issues of a public affairs nature. During this investigation, the Board received comments from LANL staff that lived near W-1 that during the RAP team deployments to his home, there was no effort to communicate to the neighborhood whether there was any cause for concern, even though the deployment was quite visible to those nearby. The Board believes that the success or failure of a RAP deployment depends as much on the public's perception of the event and DOE's response to them as on the actual facts surrounding the technical and operational response.

The Board concluded that failure of the recent policy change to provide for a PIO during the RAP deployments is in direct conflict with DOE Order 151.1B and other DOE requirement and guidance documents. In addition, the Board noted numerous examples in this investigation as to why this position is critical to the teams. Questions concerning survey of public areas, acceptable release criteria or practices, sensitive communications with impacted personnel, and media communications all benefit from the expertise of a PIO. The Board believes that NA-40 should review this policy change, and if in fact it is to be implemented, then clear guidance must be developed for the handling of these issues.

In cleaning up identified contamination, the RAP and Decontamination teams basically used a criterion of "if we can detect it we will either clean it up or dispose of it as contaminated waste." Formally, DOE's expectation for the RAP teams is that they will follow the criteria established by the requesting entity. When the Board discussed release criteria with RAP personnel, the requirements contained in 10 CFR 835 were cited as the governing values for this series of deployments. However, the 10 CFR 835 criteria only apply for occupational settings where items are released from a radiological area to a controlled area. In actuality, DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, is the governing document for the free release of materials, equipment, and property to uncontrolled areas.

For most radioactive materials the release requirements are the same; however, for transuranics such as americium the release criteria in DOE Order 5400.5 are more restrictive than those in 10 CFR 835. While the teams' informal criteria of cleaning or removing all contamination might appear to negate this issue, there is more that must be considered. The applicable release criteria will define the detection capabilities necessary for the instruments and sampling techniques selected for the situation at hand. For example, in discussion with RAP personnel, it was indicated that the minimum detectable activity for the portable instrumentation currently used is about 200 dpm/100-cm^2 compared to the DOE Order 5400.5 criteria of 20 dpm/100-cm^2 for removable and 100 dpm/100-cm^2 for fixed contamination. To address this concern, the teams would have to rely on a combination of field instruments and laboratory analysis of swipe samples, where lower detection levels can be obtained. In the case of these deployments, the teams did use a combination of field instruments and laboratory analyses, so even though the incorrect criteria were applied the decisions made were adequate. Regardless, the Board believes that NNSA needs to ensure that the RAP teams are provided clear "default" criteria for deployments in the public domain, to be followed unless the requesting entity is under the jurisdiction of another regulatory agency with different criteria.

During the response to the offsite impacts, consideration was given to surveying public areas such as commercial businesses where W-1 was believed to have visited; however, due to a concern about maintaining a low public profile, and the expectation that any contamination would be below a level for human health concerns, these surveys were not completed. The one exception to this was the survey of the hotel in Great Bend, Kansas. This deployment was driven by an NA-10 request. While the desire to keep a low public profile is understandable, activities must be conducted in a manner consistent with accomplishing the overall objectives. The Board recognizes the difficulty and concerns in conducting surveys of large businesses, such as large grocery or department stores; however, RAP teams must be prepared to conduct such surveys if warranted by the potential contamination levels. The use of pre-identified criteria for making such decisions is preferable to ad hoc decisions made during the operation. The Board believes that NNSA needs to establish clear criteria, taking into account both technical and societal considerations, for when survey activities in publicly occupied areas are required in response to concerns that radiological contamination might exist in those areas.

The Board concluded that the DOE RAP teams did not have clearly defined criteria for the release, decontamination, or confiscation of radioactively contaminated personal property discovered in the public domain.

The Board concluded that the DOE RAP teams did not have clear guidance or criteria for determining when it is necessary to conduct radiological survey activities in publicly occupied areas.

3.4 LANL's Radiation Protection Program

The responsibility for the LANL Radiation Protection Program resides with the HSR Division. The LANL Radiation Protection Program Manager (RPPM-1) is responsible for establishing the institutional program and providing guidance for its implementation. The HSR-1 group is responsible for supporting the line implementation of the operational aspects of the program. All of the RCTs and operational health physics SMEs at LANL are members of this group and are deployed through a matrix concept to line organizations conducting radiological activities. Other HSR groups provide support services such as analytical services, calibration services, radiological logistics, and dosimetry. The Radiological Protection Program (RPP) is implemented through development of Laboratory Implementing Requirements and Laboratory Implementing Guides. Additional operation-specific procedures are developed on a facility basis. Essential to the LANL RPP is field implementation of the requirements; in this sense line organizations and all radiation workers are key members of the RPP.

HSR-1 operational support to line management is established and defined through use of Radiation Protection Support Agreements. The line management provides the funding for this support; approximately 95% of the total HSR-1 budget is directly funded in this manner. The remaining 5%, provided by laboratory overhead accounts, is used to fund core requirements such as staff for the training and qualifications program, procedures development and maintenance, quality assurance, automation and data base maintenance, and maintenance of a general monitoring pool. This monitoring pool provides personnel to meet short-term support demands, backfill assigned support positions during training and other absences, equipment maintenance, and logistical support.

The Board was very concerned with the emphasis on direct versus indirect funding for the LANL radiation protection program. Requisite overhead funding is necessary to allow for the program infrastructure that supports the independent assessment and corrective action implementation. Further, the Board was concerned with the turnover in HSR personnel. More specifically, LANL reported that 16% of the RCT workforce leaves the organization annually for more attractive positions at LANL; thereby, directly affecting the continuity of program implementation. Also, the limited amount of indirect funding has resulted in the reassignment of essentially all of the monitoring pool staff to other tasks, leaving the pool unable to satisfy the demands placed on it. In fact, HSR-1 management reported that the pool is essentially unfunded for fiscal year 2006, and will be deleted from the organizational chart. In this accident, the lack of adequate staff in the monitoring pool complicated the efforts to support the response activities. It was necessary to pull RCTs from other facilities, leaving them understaffed.

The MST Division has a radiological support staff of three full-time HSR-1 personnel, consisting of two RCTs and one RCT supervisor. In addition, MST supports 15% of the time for an HSR-1 team leader, who also acts as the primary health physics SME for the Division. In addition to supporting daily operations in Sigma and the other MST facilities, these personnel are also responsible for conducting routine surveillance activities to monitor the radiological conditions within the facilities and to maintain the facilities' compliance with LANL's RPP requirements and 10 CFR 835. Operational support requests are documented and tracked in a Radiological Services Request System managed by MST.

As a less-than-category 3 radiological facility, Sigma relies on its FSP to establish limits on the types and quantities of radioactive material that can be brought into the facility. The FSP specifies that limit based on the DOE-STD-1027 appendix listing of threshold quantities for Category 3 inventories. Sigma's actual inventory is compared to the DOE-STD-1027 appendix by taking the ratio between the actual inventory of each individual isotope and its category-3 threshold quantity. The individual fractions are then summed, and as long as the sum of the fractions is less than one the facility is within its limits. The implication of this is that Sigma is authorized to receive any radioactive isotope listed in DOE-STD-1027 as long as the quantity does not cause their total inventory to exceed the category-3 threshold. As an example, the category-3 threshold value for Am-241 is 520 millicuries, and the amount introduced during this event was about 4 millicuries, so the sum-of-the-fractions value for Sigma increased by about 0.008. In contrast, during multiple interviews and discussions LANL staff informed the Board that Sigma was only allowed to work with depleted uranium or small quantities of enriched uranium, and therefore the radiation protection program at the facility was only designed to accommodate that type of radioactive material.

In reviewing information concerning the response to the accident, the Board noted a number of weaknesses in the Sigma, PF-4, and HSR RPPs. These include weaknesses in procedure development and implementation, hazard assessment, hazard control, training, and management.

The Board identified RPP procedure implementation weaknesses at PF-4 that included failures on the part of the RCTs to label the shipment for secondary contamination hazards and to complete the HPRMS to indicate the presence of contamination (see Section 3.6). At Sigma, W-1 opened the shipping container without RCT support (see Section 3.6). NMC-1 set off a hand-and-foot monitor and never reported the event to the RCTs (see Section 2.2), which is in direct contradiction to the requirements established in radiation worker training. MST-6 failed to ensure that receipt inspections were being conducted for incoming radioactive material shipments (see Section 3.6). The Sigma building surveys conducted during the response activities were not formally documented in a timely and complete manner. As such, the information was not complete and brought in to question the adequacy of the survey effort (see Section 3.1). The RCTs used a whole body personnel contamination monitor to release W-1 after decontamination rather than a more sensitive and comprehensive survey for alpha contamination using instrumentation sufficient to detect the contaminant present. While it is understood that whole body monitors are automated and greatly reduces error in frisking by the individual, the distance of the probe surface to some portions of the body precludes the adequate detection of alpha emitting radionuclides when high sensitivity is required.

The Board identified weaknesses in hazard assessments that included the failure to evaluate or denote contamination of the Swageloks® by the PF-4 RCTs and NMT-4 (see Section 3.6). Personnel were allowed back in Sigma prior to adequate characterization of affected areas (specifically R108); thereby, allowing the potential for additional personnel exposure to the incident (see Section 3.2). Radiological surveys conducted at Sigma did not always evaluate the removable fraction of the contamination (see Section 3.2). Unless assumptions are made that the entire source term was removable due to the incident, realistic interpretation of the hazard cannot be made. Incorrect interpretation of the surface radioactivity guidelines allowed the use of incorrect release criteria at both Sigma and during the RAP deployments (see Sections 3.2 and 3.3).

The Board identified weaknesses in the development and implementation of hazard controls in that the criteria developed for re-evacuation of the facility were technically flawed and inconsistent with 10 CFR 835 and DOE O 5400.5 (see Section 3.2). Sigma was ill equipped to respond to incidents due to the lack of available posting materials and instrumentation (see Section 3.2). Sigma's HSR personnel were not familiar with the alarm set point for the CAM or the Derived Air Concentration (DAC) for americium-241. Routine Monitoring Instructions Surveys conducted in Sigma were inadequate to identify the spread of contamination from this event.

The Board identified weaknesses in radiological work practices that included an inadequate worker understanding of how to respond to frisker alarms at Sigma. NMC-1's failure to contact HSR personnel when the frisker initially alarmed precluded a more timely identification of the incident. The Board identified weaknesses in training qualifications in the failure to identify the need for nuclear material handler training for W-1. The nuclear material handler training clearly specifies requirements for TID removal. If those requirements had been followed, it is believed that the need for additional controls might have been recognized.

The Board identified weaknesses in management, including that the HSR assessment program failed to identify programmatic deficiencies and/or implement corrective actions relative to the requirements established for receipt inspections of incoming radioactive material. The compartmentalization within the HSR-1 and between Directorates resulted in a poor understanding of hazards at other facilities and poor communications of hazards between facilities. Assumptions were made but not verified that the respective organizations understood the inherent hazards associated with material that had been generated in the glovebox at PF-4. HSR instrumentation used in response to the incident was not adequately sensitive to detect Am-241 at free-release levels required by DOE O 5400.5. Exemptions to this detection expectation had not been applied for as allowed by DOE. The Board was informed that LANL and LASO had previously identified this concern and has a process in place in lieu of a formal approval from DOE.

The Board concluded that the implementation of the LANL radiation protection LIR and the requirements of established regulations were not effective or adequate.

The Board concluded that the radiation protection program at Sigma was not designed consistent with the types and quantities of radioactive material that the facility was authorized to receive and handle by its FSP.

The Board concluded that the Sigma radiation protection program was implemented based on an ***assumed requirement*** *that the facility was only authorized to work with uranium, in contradiction to the FSP.*

The Board further concluded that Sigma and HSR have inadequate RCT staffing to effectively implement a RPP for Sigma. The Board is also concerned that this staffing shortfall may extend to the Los Alamos Laboratory in general due to the direct versus indirect funding ratios.

3.5 LANL's Material Control and Accountability Program

The MST-6 Material Control and Accountability (MCA) Custodian (NMC-1) has the primary responsibility for inventory and tracking of accountable nuclear material movements within Mass Balance Area (MBA) 510, which includes Sigma, as well as all radioactive material shipments entering and leaving Sigma. Administrating the TID program and performing MASS system transactions for Sigma are included in these responsibilities.

The MST-6 Foundry and Machining Team Leader (NMC-2) has the responsibility as Team Leader for the MCA program that includes day-to-day supervision of NMC-1, being an Alternate MCA Custodian, MASS system user, and an authorized receiver of radioactive shipments into Sigma. LANL team leaders are not defined as managers, and therefore NMC-2 has no formal safety oversight responsibilities with regard to NMC-1 or the rest of NMC-2's team.

MCA program requirements are contained in the MCA Custodian Handbook. A Material Balance Area Operations Plan (MBA/OP) provides local implementation. Accountable nuclear material shipments are coordinated between shipping and receiving organizations in advance of the actual shipment. This coordination includes telephone calls, MASS system input, and several required documents.

An IWD for packaging and shipping radiological materials from Sigma was in place prior to July 14, 2005. RCT support is required to survey and label the outgoing package and sign the required documentation. RCT support can be requested through a computerized request and scheduling system. The records indicated that some RCT support has been requested for outgoing shipments, but no RCT support had been requested for incoming shipments for at least one year. Informal verbal requests for RCT support are common.

The Board concluded that RCT support is not routinely requested through the established management system but is informally and verbally requested for immediate response.

An IWD for receipt of radiological materials at Sigma does not exist, thus there is no mechanism for establishing RCT support requirements. During interviews NMC-2 indicated that she thought this might be a potential failure to implement the LANL requirements. NMC-2 was aware that other facilities implement this requirement, but had an ***implied assumption*** that the other facilities are going above and beyond the requirements.

Sigma's radiological control operations were reviewed during the 2004 stand-down of LANL operations. HSR personnel participated in that review but failed to recognize the lack of documented receipt inspections. During interviews, RCTS-1 noted that the RCTs had previously expressed concerns that receipt inspections were not being requested or performed, and she had discussed the concern with NMC-1, but did not bring the issue to management attention. No further action was taken. Radioactive material receipt inspections are a requirement of 10 CFR 835 that is directly carried forward in the LANL requirements, including the Sigma FSP.

The Board concluded that a radiological material receipt IWD does not exist for Sigma.

The Board concluded that RCT support is not routinely requested or used for radioactive material shipment receipt inspections as required by 10 CFR 835.

The Board concluded that the 2004 stand-down and resumption process failed to identify the lack of ISM work planning for receipt of radiological materials.

The Board concluded that the Sigma RCTs previously recognized the lack of radiological receipt inspections, but no formal action was taken to correct the deficiency; therefore failure to conduct receipt inspections is an **accepted practice** *at Sigma.*

The Board concluded that safety responsibilities are not defined at the Team Leader level.

When the shipment was received at Sigma on July 14, the shipping drum had a TID affixed. NMC-1 did not process the TID according to the MCA Custodian Manual requirements. The TID program requires two qualified TID users, a remover and a verifier, to process the TID for removal. The TID removal form must be completed, and the MASS system updated to report the removal of the TID. NMC-1 did not know there was a second TID on the inner Hagan can. This TID was also not processed according to established procedures. MBA 510 has six qualified TID users and two qualified TID custodians available to perform these functions. NMC-1 is a qualified custodian, but W-1 was not qualified to perform any TID functions.

The pellets were contained in individually serial numbered Swageloks®. NMC-1 did not attempt to inventory or verify these serial numbers at the time of receipt, as is the normal procedure. NMC-1 reportedly had a time conflict due to the expected arrival of another shipment at a different loading dock in Sigma, and did not complete the receipt process at the time of receipt of the shipment. MASS system records indicate one other shipment on July 14. NMC-1 turned the shipment over to W-1, and requested that he verify the serial numbers.

Nuclear Material Handler training is required by those who possess or use nuclear material. W-1 did not have Nuclear Material Handler training and NMC-1 did not verify that before transferring custody of the shipment.

NMC-1 had an ***implied assumption*** that W-1 had the required training and did not know how or where to verify training qualifications. Every LANL employee's training record is available in an online training database that NMC-1 could access.

NMC-1 updated the MASS system later that day. The MASS system records the TID number for a shipment, and it needs to be removed from the system when the TID is removed from the container. Records indicate that the TIDs were not removed from the MASS system until September 15. NMC-1 later posted a list of the serial numbers for the Swageloks® on W-1's office door to have him verify them. The Board believes that NMC-1 should have been aware of the TID on the drum and followed the procedure to remove it (and discover the second TID). NMC-1 assumed that W-1 would have recognized the significance of the TID on the drum and would not open it. The requirement that only qualified personnel can remove TIDs is taught to workers as part of the nuclear material handler module; since W-1 had not been required to take that module he was not aware of that requirement.

The Board concluded that the MCA receipt process for this shipment was not completed in a timely manner due to competing priorities.

The Board concluded that the TID removal process was not conducted according to established procedures.

The Board concluded that workers did not have the required training and qualifications for the work they are assigned and that those requirements were not verified.

W-1 did not have an IWD for receipt and storage of the pellets. The IWD process includes an online template that assists in identifying hazards and control requirements. It also identifies required training for that particular activity. The IWD process expects that the IWD preparer and the PIC identify the training requirements (IWD worker, IWD PIC, IWD preparer, TID user, Nuclear Material Handler, etc.) and would have expected that a radiation protection SME establish appropriate controls and concur on the IWD. W-1, in the role as the PIC for the activity, would not have realized that he did not have the required IWD training, and did not recognize the need for Nuclear Material Handler training. The IWM process requires the Responsible Line Manager (RLM) to assign and approve all workers on an IWD to include verifying their training and qualification for that IWD. Since the IWD was not prepared the RLM could not satisfy that requirement. Consequently, W-1 moved the drum to room R3, removed and discarded the TIDs, opened the containers without RCT support, and verified the serial numbers of the Swageloks®, thus initiating the contamination events.

The Board concluded that an IWD was not prepared for receipt of this material, thus failing to define the scope of work, analyze hazards, develop and implement hazard controls, work within those controls, and provide feedback and continuous improvement.

The Board concluded that radiological material containers were opened and radiological materials used without RCT support on a routine basis, and this was therefore an ***accepted practice*** *at Sigma.*

3.6 LANL's Radioactive Materials Transportation Program

On July 7, in preparation for the shipment of the uranium nitride pellets from PF-4 to Sigma, they were moved from G138 in room 126, through the trolley, into G150, and then into a hood in room 128. Before removal from G138, the Swageloks® containing the pellets were placed into a plastic bag that was sealed, and then during removal from the hood, that bag was placed inside two additional plastic bags. The exterior of each bag was wiped down to remove contamination. The outer two bags were monitored and determined to be free of contamination. These surveys were not documented. The Swageloks® were then placed into a Hagen can that was moved to room 124 of the PF-4. There the can was surveyed to determine gamma and neutron exposure rates. According to the shipping labels, these were determined to be 1.0 mr/hr gamma and 0.2 mrem/hr from neutrons. The Hagen can was labeled with a "Caution Radioactive Materials" label and placed in the safe in room 127 pending transfer to NMT-4 for final packaging and preparation for shipment to Sigma.

On July 12, the Hagen can was transferred to NMT-4 for final packaging and radiological surveys. A survey was completed for the 30-gallon Type A drum to be used as the outer shipping container, and a Health

Physics Radioactive Material Survey form was completed. Section 2 of the tag was marked to indicate the presence of "Radioactive Material/Source"; however, the tag was not checked to indicate the presence of contamination. Section 3 of the tag, "Survey of Bare Material," was marked as not applicable. Section 4 of the tag, "Survey of Packaged/Shielded Material," was marked as non-detectable activity for both contamination and radiation surveys.

On July 14, the "Radioactive Materials Transfer" form was completed. SUP-5 picked up the shipment and delivered it to the south dock at Sigma. NMC-1 signed for the shipment, entered it into the MASS system, and turned the package over to W-1. This work was completed without a receipt inspection of the shipment, even though one is required by LANL requirements. A review of the records for receipt and inspection of incoming radioactive material shipments indicated that shipments were routinely received without receipt inspections being conducted. The Board requested shipping papers and receipt inspection reports for all shipments received at Sigma for the period between January 2004 and August 2005. The Board was provided 36 documents for shipments brought into Sigma and five receipt inspection reports for the same period. None of the receipt inspection reports corresponded to any of the shipment documents (see Section 3.1.3).

In the shipment involved in this accident, the Am-241 consisted of contamination on the actual sources being shipped; however, the americium activity exceeded that of the uranium by several orders of magnitude. The shipping manifest failed to adequately implement DOT requirements for identifying the major radiological components of the shipment. In addition, the information provided did not adequately reflect the hazard of the material being shipped. The Board believes that NMT's failure to identify and include Am-241 on the shipping manifest represents a violation of DOT transportation regulations.

Both LANL and DOE radioactive material labeling requirements are intended to ensure that all radiological hazards represented by the material are adequately conveyed to the user. In preparing the shipment, NMT-4 did not identify the secondary hazard represented by the contamination on the Swageloks® through the use of labeling on the packaging. Also, the Health Physics Radioactive Material Survey Tag did not include the appropriate checkmark in Section 2 to identify the presence of contamination on the packaged material, nor was Section 3 completed to indicate the levels of contamination present on the bare material. The implementation of these requirements is not consistent with the intent of the guidance documentation.

The Board concluded that the labeling of the material and shipment did not comply with applicable LANL requirements.

The Board has noted that MST's omission of the receipt inspection, required by DOT, DOE, and LANL, and opening of radioactive material shipments without RCT support have become **accepted practices** at Sigma. While there seems to be no LANL procedural requirement for an RCT's involvement in opening received shipments, this is contrary to normally accepted standards.

The Board concluded that poor radiological practices, coupled with the failure to accurately identify and communicate the hazard presented by the presence of the contamination, were significant contributors to this accident.

3.7 Formality of Operations

This section discusses the formality of operations that the Board determined to be in place during the time of the accident, and it evaluates the relationship between that formality and the occurrence of the accident. This section will primarily collect information established in the other sections and then consider what the collection indicates about the state of operational formality at the time of the accident. The Board separately considered the formality of operations at PF-4, Sigma, LANL institutional processes, and LASO.

The PF-4 facility is a hazard category-2 nuclear facility, and has documented and DOE-approved Authorization Basis and Conduct of Operations programs in place. Sigma is a radiological facility, and as such DOE expects that a graded approach be taken to tailor the authorization basis and conduct of operations concepts to a level commensurate with the facility's hazards. Due to this difference between the facilities, the Board does not expect to find the same level of formality at both facilities, so no comparisons will be drawn between the facilities.

PF-4

The project to fabricate the uranium nitride pellets for Bettis was assigned to the NMT-11 group at PF-4. As a Hazard Category 2 nuclear facility, PF-4 has developed and implemented a formal conduct of operations process. The uranium nitride fabrication project involved re-establishing a processing capability that had not been in operation for more than a decade. In addition, the customer, Bettis, had established very restrictive specifications for the quality of the product. Therefore, a significant amount of project planning and preparation was necessary before the work could be performed. Since the work was being performed in a pre-existing glovebox line, NMT-11 was able to apply many of the existing work procedures and safety controls that are generic to working in gloveboxes.

In reviewing the PF-4 aspects of this accident, the Board recognized that the potential for contamination on the pellets and the Swageloks® was an inherent part of working in contaminated gloveboxes. Therefore, the Board did not spend a significant amount of time reviewing the project-specific safety controls. Rather, the Board focused on two areas that it believed to be most germane to this accident: (1) the interactions between NMT-11 and MST-6 during the planning for the work at Sigma, and (2) the removal, packaging, and shipping of the material to Sigma.

The Board's focus on the interactions between NMT-11 and MST-6 concerned whether the potential for contamination on the material being provided to Sigma had been communicated from NMT-11 to MST-6. In Section 3.1, the Board determined that although there had been multiple meetings between NMT-11 staff and MST-6 staff, and that NMT-11 had asked MST-6 about whether Sigma could work with the materials within their facility limits, but that there had been no explicit discussions regarding the potential for contamination on the material being provided to Sigma. The Board determined that both groups had been operating under ***implied assumptions*** that were never verified. NMT-11 knew that, since the pellet work and assembly of the Swageloks® was being done in the same glovebox as other americium and plutonium work, there was likely to be significant levels of contamination on the parts when removed from the glovebox. However, NMT-11 assumed that, since the material was going into another glovebox, that MST-6 would know that the materials would be contaminated and would be able to handle them appropriately. In contrast, MST-6 assumed that NMT-11 knew that they could not handle highly contaminated material and that NMT-11 would decontaminate the material before shipping it to Sigma. Therefore, MST-6 assumed that the only contamination on the material would probably be low levels of uranium contamination, which they were prepared to deal with. The Board believes that since NMT-11 was the lead for the project, the provider of the material for Sigma, and the most knowledgeable party regarding the likely hazards associated with the material, NMT-11 should have ensured that MST-6 was informed of the full radiological status of the material and prepared to accept it.

The Board concluded that NMT-11 did not ensure that MST-6 was aware of and prepared for the potential for significant contamination on the material before shipping the package to Sigma.

The Board concluded that, based on interviews with PF-4 staff, the ***implied assumption*** *that somebody receiving a shipment from PF-4 would automatically assume that it was contaminated was a* ***latent condition*** *in that it represented the normal mode of operation at PF-4.*

LANL, DOE, and DOT requirements for shipping of radioactive material are designed to ensure that the package is transported safely at a very low risk to the transporter and the public, and to ensure that the receiving entity is fully informed of the radiological condition of the contents of the shipment. In Section 3.6, the Board determined that the surveys and labeling performed by NMT-4 and the PF-4 RCTs did not conform to PF-4 procedures, LANL requirements, or DOT requirements. Also, in Section 3.1, the Board determined that this failure to adhere to shipping procedures by NMT-4 and the PF-4 RCTs was an **accepted practice** based on the frequency of its occurrence and discussions with PF-4 staff.

The Board concluded that NMT's formality of operations was less than adequate in that hazards inherent in the material shipped to Sigma were not properly communicated to MST-6, either through NMT-11's project execution processes, or through the proper surveying and labeling of the shipment by NMT-4 and the PF-4 RCTs.

The Board also concluded that the ***accepted practice*** *of failing to adhere to shipping procedures indicates a weakness of the Conduct of Operations program at PF-4.*

The Board concluded that the failure to adhere to shipping procedures by NMT-4 and PF-4 RCTs was a ***latent condition*** *in that it represented the normal mode of operation.*

Sigma

The bulk of the Board's investigation focused on operations at Sigma both leading up to and following the initiation of the accident until its discovery. Since the delay in the discovery greatly reduced LANL's ability to minimize the impacts of the accident, the Board considered the eleven days between the initial opening of the package in R3 and the discovery of the contamination as part of the accident progression.

In the Sigma operations, the Board encountered a large number of failures to adhere to MST-6 and LANL institutional procedures, policies, and requirements. The Board determined that several of them were ***accepted practices*** within the facility. Significant examples of these non-adherences include:

- Washing hands and retesting after setting off a frisker alarm was an ***accepted practice*** among Sigma workers, even though it was contrary to LANL requirements;
- The development, use, and acting as PICs for IWDs by workers without the required training was an ***accepted practice*** at Sigma, contrary to LANL IWM requirements;
- The failure to develop and use an IWD for receiving and opening radioactive material shipments at Sigma was an ***accepted practice***;
- The failure to have receipt inspections conducted on receipt of radioactive material shipments was an ***accepted practice*** at Sigma, contrary to LANL and DOE requirements;
- The removal of the security TIDs on both the shipping drum and the Hagen can was not conducted in accordance with MST-6 procedures and LANL requirements;
- The failure to inform the RCTs of incoming radioactive material shipments was an ***accepted practice***; and
- The authorization of work under an IWD without appropriate training was an ***accepted practice***.

The Board concluded that, based on the large number of procedural non-adherences that have developed into ***accepted practices*** *at Sigma, there is essentially no formality of operations at the facility.*

The Board concluded that, given the large number of ***accepted practices*** *at Sigma, all procedural non-adherences involved in this accident were* ***latent conditions*** *that existed in the facility.*

In addition to weaknesses in the conduct of the workers, the Board identified a number of weaknesses within the management systems at Sigma that the Board believes need to be considered:

- MST management allowed workers to develop, use, and act as PICs under IWDs without assuring that they had the appropriate training;
- MST management's assessment processes were not effective in identifying and correcting the large number of procedural adherence deficiencies and ***accepted practices*** identified by the Board;
- MST management did not adequately document and communicate safety roles and responsibilities throughout the organization;
- MST management did not ensure that workers had the necessary and appropriate training for the work they were assigned; and
- MST management did not ensure that those procedural non-adherences and ***accepted practices*** that had been identified by their assessment processes were corrected in a timely and effective manner.

The Board concluded that MST management has not adequately fulfilled its responsibility to instill a level of formality of operations at Sigma that is commensurate with the hazards; protective of the workers, public, and the environment; and consistent with the LANL and DOE's implementation of Integrated Safety Management.

The Board concluded that the failure of MST management to instill an appropriate level of formality of operations at Sigma is a ***latent condition.***

LANL Institution

The Board also considered LANL's institutional processes and programs with regard to the structure and oversight they provide for operations at PF-4 and Sigma. In Section 3.8, the Board evaluated the LANL feedback and improvement processes and their relationship to this accident. The Board determined that most of LANL's institutional assessment processes had not focused on Sigma, due to its categorization as a less than hazard category-3 radiological facility, for multiple years. However, the Board did determine that multiple assessments had identified issues that were directly related to this accident, but those issues had not been addressed in a timely or effective manner. The Board believes that, without institutional attention, MST management was not motivated to take proactive action in identifying and correcting deficiencies in work practices and processes implementing LANL institutional requirements.

The Board also determined that the failure to fully complete radioactive shipping papers at PF-4 was an ***accepted practice***. The Board believes that an effective institutional oversight program could have detected this ***accepted practice*** through routine reviews of the documentation and procedures used for preparing radioactive material for shipment.

The Board concluded that the lack of LANL institutional oversight of Sigma operations contributed to the failure of MST management to instill an appropriate level of formality of operations at the facility.

The Board also concluded that LANL's institutional oversight processes were inadequate to detect and force the correction of weaknesses in the shipping processes at PF-4.

The Board concluded that the lack of adequate LANL institutional oversight was a ***latent condition.***

NNSA Institution

Finally, the Board considered the role of NNSA, and in particular LASO, in their roles as line managers of LANL, PF-4, and Sigma. The Board noted in Section 3.9 that LASO had self-identified concerns regarding staffing and resource limitations, and they demonstrated weaknesses in managing the timely and effective closure of issues involving LANL. Furthermore, the Board determined that NNSA was not effective in providing guidance, resources, and oversight of LASO to assist LASO in addressing their programmatic weaknesses. As a result, LASO management has shifted the focus of their limited staff and resources to conducting oversight primarily of the higher hazard nuclear facilities and, to the extent possible, selected LANL institutional programs. Consequently, LASO has not had a viable presence in Sigma for multiple years. The Board believes that this lack of attention, coupled with LANL's lack of institutional attention on Sigma, contributed to the absence of formality of operations at Sigma.

The Board concluded that the failure of LASO to maintain a viable level of presence at Sigma and attention to Sigma operations contributed to LANL's failure to establish and maintain an adequate and effective formality of operations at the facility.

The Board concluded that this failure to maintain a LASO presence at Sigma was a ***latent condition****.*

Summary Conclusion

In this investigation, the Board determined that all conditions that contributed to this accident were ***latent conditions***. The Board was able to demonstrate a direct tie between deficiencies in formality of operations and weaknesses in feedback and improvement that allowed those deficiencies to continue to exist and proliferate. The Board also determined that the weaknesses in feedback and improvement extended through essentially all levels of LANL and NNSA. Those weaknesses were direct contributors to this accident. The Board believes that, in essence, this was a classic example of an accident waiting to happen.

The Board concluded that this accident could have been easily prevented, and all operational failures that led to this event were ***latent conditions*** *that could have been detected and corrected.*

Furthermore, the Board concluded that failures of feedback and improvement processes within both LANL and NNSA were primary contributors to the continued existence of those ***latent conditions*** *that led to this accident.*

3.8 LANL's Feedback and Improvement Programs

The Board determined that several LANL institutional feedback and improvement processes are applicable to the facilities and organizations that are involved in this accident. The Board chose not to evaluate those processes in depth, but rather to review recent results of those processes to determine if any issues identified may have some relationship to this accident.

MST Feedback and Improvement

All LANL facilities underwent resumption reviews as part of the recovery from the LANL Director's stand down of July 2004. Those resumption reviews were conducted using a rigorous and comprehensive process established by LANL specifically for this purpose. Corrective actions for pre-start findings were required to be implemented before the facility could restart, the others could be completed later as long as adequate compensatory measures were in place. The Board reviewed the products of the Sigma facility resumption efforts to consider the relevancy of any identified issues to this accident. The Board then reviewed the status of corrective actions developed in response to any relevant issues. The Board noted five of the MSA-identified issues that the Board considered to have relevance to the activity underway when this accident occurred:

- "Although technically compliant, MST Management Walkaround Program lacks robustness to fully and comprehensively assess work and workers." (substantive observation)
- "MST document control and assessment/incident response systems lack sufficient maturity to be maximally effective." (post-start finding)
- "Hazard identification, especially relative to secondary hazards, would be substantially improved by greater and more effective use of [SMEs] and peer review." (substantive observation)
- "Inadequate coupling exists between employee training plans and IWD requirements to effectively assess worker qualification status." (substantive observation)
- "MST Facility Safety Plans (especially Sigma Complex FSA) need to be updated/validated. On-going efforts have already made substantial progress in addressing these issues and should be continued." (post-start finding)

The LRR identified the following issues the Board considered to be relevant to this accident. In most cases, these issues overlap those identified in the MSA.

- "The organization does not have a Quality Assurance Program as required by 10 CFR 830.120 Subpart A." (post-start finding)
- "Throughout the documents reviewed, great reliance is placed on worker knowledge rather than formal training to accomplish the assigned task. While the hazards are adequately identified, determination of whether to perform all steps, and the order of performance, is sometimes left up to the worker. The IWDs should more formally control the performance of the task, especially for higher risk activities." (substantive observation)
- "LIR 300.00.04.2, Section 5.3 requires line management perform an analysis of training requirements and document their decision related to determining the graded approach to training development. There was no evidence found to indicate that line management documented the analysis or the determination of the graded approach. The

analyses performed for the IWDs do not meet the intent of this requirement. No training materials for job training were found for the operations reviewed." (post-start finding)

- "LIR 300.00.04.2, Section 6.3.2.2, the additional rigor requirements for written tests or evaluations and written documentation of qualification ("qual cards") signed by line management, and continued training are not met nor performed." (post-start finding)

The MST organization has developed a resource-loaded corrective action plan to address the findings and substantive observations of the MSA and the LRR. Many of the MST corrective actions related to the above issues are still in progress, including the following:

- Update the FSPs, due November 30, 2005.
- Develop a formal surveillance program and plan, due November 30, 2005.
- Develop an updated Integrated Work Management Procedure for MST Division, due November 30, 2005.
- Implement a mechanism to document worker authorization within the IWD procedure, November 30, 2005.
- Develop and implement a Quality Assurance Program for MST to meet requirements of 10 CFR 830.120, due September 15, 2006.
- Develop and implement a self-assessment program for MST, due October 1, 2006.
- Develop and implement a process to ensure annual line management review of worker training plans, due August 31, 2007.
- Develop a worker qualification process/ program based on IWD requirements, due August 31, 2007.

In accordance with LANL policy, MST has an ongoing Nested Safety and Security Committee that meets monthly to review the status of safety and security in the MST facilities. At these meetings, the committee reviews the current safety and security performance metrics, discusses ongoing systems and standards development, and shares information regarding issues identified since the last meeting. A review of the minutes of the last 6 months of meetings did not disclose any issues directly related to this accident. However, it was noted by the Board that the Group Leader of MST-6 consistently and significantly exceeded the established goals for conducting Management Walkarounds (MWA) for the full year. The Board reviewed the MWAs conducted by this individual over the last year and found that they appeared to be effective in identifying worker safety and security issues. However, those issues were deemed to be irrelevant to this accident.

In July and August 2005, the Transportation and Packaging Division (SUP-5) conducted an assessment of packaging and transportation (P&T) operations performed by MST-6 and MST-10. [Note that this SUP-5 assessment team recognized that the accident under investigation here had occurred while their work was in progress, but did not evaluate it since this accident investigation was beginning.] The SUP-5 assessment process is guided by a comprehensive set of criteria for evaluating compliance with the DOT and LANL requirements for packaging and shipping. However, there are no criteria designed to evaluate the LANL, DOT, and DOE requirements for receipt of radioactive packages. The SUP-5 assessment resulted in five deficiencies and two observations. Those issues that the Board believes are relevant to this investigation are:

- "Based on interviews with MST-6 P&T personnel, P&T records are being maintained by the individuals but not processed into a records management system. There is no division records management system that governs P&T records. This has been self-identified by MST during the recent MSA/LRR resumption effort." (deficiency)
- "Based on interviews and lack of documentation, a management assessment

program that includes packaging and transportation activities has not been fully implemented in MST. This has been self-identified by MST during the recent MSA/LRR resumption effort." (deficiency)

- "Based on interviews and documentation reviews, the quality assurance program has not been fully implemented to include P&T activities. This would include a process to document and manage to closure identified non-conformances and a process to support the purchase, inspection, and documentation of quality items for packaging and transportation activities and materials. This has been self-identified by MST during the recent MSA/LRR resumption effort." (deficiency)

In other sections of this report, the Board has determined that there were several conditions that contributed to this accident. Those conditions that the Board believes were within MST's purview include (1) a weak and faulty IWD implementation; (2) inadequate worker training; (3) inadequate self-assessment, audit, and record-keeping processes; (4) poor formality of operations (procedure adherence); (5) ineffective communication of administrative controls and requirements to the workers; and (6) inadequate monitoring of the conduct of work in accordance with the established controls.

The Board concluded that the issues identified above through both MST and LANL assessments are direct indications of the existence of the conditions identified in this investigation.

During this investigation, the Board reviewed MST-6 records of receipt inspections of radiological shipments and compared them to SUP-5 records of radiological shipments into the facility for the past two years. The Board could find no direct correlation between the two sets of records, suggesting that receipt inspections were not routinely being performed at Sigma. The Board also identified other similar records that could be audited to assess compliance with established requirements, but the Board could not find evidence that any party had recently audited these records.

The Board concluded that radioactive material receipt inspections at Sigma are not routinely audited or assessed to verify compliance with LANL and Federal requirements.

The Board concluded that the MST assessment processes do not adequately evaluate for and determine the level of compliance with established requirements.

NMT Feedback and Improvement

The Board did not conduct an extensive evaluation of the NMT feedback and improvement processes as a part of this investigation. This is due to the Board's consideration that the NMT failures that contributed to this accident fell into two well-defined categories: (1) inadequate communication to MST-6 of potential hazards associated with the package being transferred, and (2) failure to fully adhere to procedures regarding the surveying and labeling of radioactive packages for shipping. The first of these contributors was considered as part of the section on ISM implementation. Regarding the second contributor, the Board reviewed other shipping papers and concluded that the failure to fully satisfy the procedures for surveying and labeling of packages appears to be a routine ***accepted practice***.

The Board concluded that NMT's feedback and improvement processes were not effective in identifying or correcting the failure to adhere to procedures and requirements for surveying and labeling packages being prepared for shipment.

The Board is concerned that procedure adherence issues may extend beyond the local activities evaluated for this accident, but believed that it was outside the scope of this investigation to pursue the concern further.

HSR Feedback and Improvement

The LANL radiation protection program is governed by Federal regulations (10 CFR 835), which included a requirement for an internal audit of all functional elements of the program on a 36-month frequency. The internal audit is required to look at both the radiation protection program content and its implementation. The Board reviewed the most recent products of this internal audit, a collection of reports that covered the period of January 2002 to December 2004. None of these reports evaluated the radiation protection program activities at Sigma; however, the Board believes that the following findings and concerns are relevant to this accident:

- "Program records were not always defined, completed, and maintained. (*repeat finding*)" (sic) (finding, Oct. 2002)

- "Line managers were not conducting self-assessments of the effectiveness of their radiation protection programs." (concern, Oct. 2002)

- "Weaknesses in formality of operations were identified in radiation control records management and in individual dose management." (concern, Oct. 2002)

- "Not all of the organizations included in this review were scheduling corrective action completion dates or completing corrective actions in a timely manner. In addition, the data presented in this report were derived from many different databases. Most databases that we reviewed did not contain a field that captured the due date for the corrective action plans." (concluding text, Sept. 2003 Addendum to Oct. 2002 report)

- "Radiation hazards and controls were not always communicated to workers through the RPP documents and processes. Without consistent communication of radiation hazards and controls to workers, the safety of workers and compliance with 10 CFR 835 could not be assured." (finding, Dec. 2003)

- "Worker inattention to the detailed requirements of radiation protection existed in monitoring for contamination control, postings for communication of radiation hazards, and records management. This inattention could lead to increases in contamination incidents and worker exposures." (finding, March 2005)

The finding of the March 2005 audit noted in the last bullet deserves further consideration. The March 2005 assessment team observed a large number of radiological activities and evaluated a sampling of postings and records. They observed deficiencies in 12.6% of the activities and identified errors in 23.8% of the postings and 3.2% of the records. As a result of this finding and the one other finding of this assessment, the assessment team concluded that "given these deficiencies, LANL could not demonstrate compliance with [LIR 402-700-01.2] or full implementation of 10 CFR 835 Subparts E, G, H, K, and L." [Subpart E is "Monitoring of Individuals and Areas," subpart G is "Posting and Labeling," subpart H is "Records," subpart K is "Design and Control," and subpart L is "Radioactive Contamination Control."]

The Board noted earlier that NMT had routinely failed to adequately adhere to procedures for surveying and labeling packages for shipping. This is a shared responsibility with HSR-1, as each organization contributes part of the information and documentation for this effort. The Board's observation of inadequate completion of surveys for shipping and receiving of radiological packages at both Sigma and TA-55 appears to be consistent with the findings of LANL's internal audits of the radiation protection program.

The Board concluded that LANL's internal assessment processes had identified multiple IWD implementation deficiencies and procedural and policy non-adherence concerns that were directly relevant to this accident, but LANL has not been effective in correcting the issues.

The Board concluded that the failure to completely survey and document the conditions of radiological packages before shipping, or after receiving, has become an **accepted practice** *that LANL has identified but not yet corrected.*

3.9 NNSA Oversight Programs

This NNSA Type B Accident Investigation was underway simultaneously with the NNSA Type B investigation of the Acid Vapor Inhalation on June 7, 2005, in TA-48, Building RC-1, at LANL. Due to the similarities between the types of facilities (both defined as "radiological facilities"), the fact that both organizations are within the same LANL Directorate, and oversight of both facilities is the responsibility of LASO, the Board decided to have the LASO oversight processes reviewed only once. Both reports address the results of that oversight review within the context of the implications to each individual accident.

Past Corrective Action Performance

DOE and LANL conducted several recent accident investigations of importance to this investigation that the Board reviewed. The purpose of the review was to assess NNSA/LASO and contractor performance in the developing, timely completion of, and effectiveness of corrective actions. While the review included all of the following documents, two of them are presented in more detail below.

- Two Workers Injured by a Chemical Explosion at TA-9-21 (May 27, 2005, LANL)
- LANL Investigation of a Laser Eye Injury (July 14, 2004)
- Independent Investigation of a Five Worker Exposure to Toxic Vapors at TA-55, PF-4 (September 27, 2003, LANL)
- Independent Investigation of an Acid Spray and Skin Contamination (July/August 2003, LANL)
- Type B Accident Investigation of the August 5, 2003 Plutonium-238 Multiple Uptake Event at the Plutonium Facility (DOE)
- Type B Accident Investigation of the Mineral Oil Leak Resulting in Property Damage at the Atlas Facility, January 2001 (DOE)
- Type A Accident Investigation Of The March 16, 2000 Plutonium-238 Multiple Intake Event at the Plutonium Facility (DOE)

The March 16, 2000, Plutonium-238 Multiple Intake Event at the Plutonium Facility

The Board reviewed the Corrective Action Plan (CAP), LANL-07/24/2000-R-AIA that was developed in response to the March 16, 2000, accident investigation.

- The DOE Corrective Action Tracking System (CATS) reported that the CAP was completed on April 28, 2005.
- The last Federal corrective action (Judgment of Need (JON) 14, Action 3) was completed on April 6, 2005.
- The last LANL action as recorded in I-Track was verified complete on April 14, 2005.

JON 14 of the Type A Investigation stated: "NNSA/DP needs to ensure that line management oversight process at LANL is being performed and is effective as specified by DOE Policy 450.5, Line Management Oversight, and DOE Standard DOE-STD-1063-97, Facility Representatives." Corrective Action number 3 addressing that JON was "Verification of successful implementation of LANL corrective actions" and the associated deliverable was "Written DOE acknowledgment to LANL that LANL has a robust, rigorous, and credible self-assessment program required by DOE P 450.5."

In January 2005, LASO, through the Change Control Board, changed Corrective Action number 3 to "Verify LANL develops, manages as a project, a Corrective Action Plan for the implementation of a robust, rigorous, and credible self-assessment program as required by DOE 450.5." The deliverable was changed to "Memorandum identifying NNSA concurrence that the implementation of the PAAA corrective action plan (CAP) (NTS-ALO-LA-LANL-2004-0018) will result in a credible self-assessment program as required by DOE Policy 450.5."

The Board concluded that the change of JON 14 Corrective Action 3 and deliverable removed from LASO the responsibility to verify LANL has a robust, rigorous, and credible self-assessment program as required by DOE P 450.5. Furthermore, the Board was concerned that the length of time taken to address the JONs arising from the March 2000 accident - 57 months - is not indicative of an organization with a strong commitment to a healthy safety culture.

The August 5, 2003, Plutonium-238 Multiple Uptake Event at the Plutonium Facility

The Board reviewed the CAP written in response to the August 5, 2003, accident investigation. The investigation report issued 13 JONs: eight were addressed to LANL, and five were addressed to LASO or NNSA.

LANL identified 25 corrective actions to address their eight JONs. LANL managed the corrective actions in the LANL Issue Management Program's I-Track system. The review found that five of those actions were overdue by more than 9 months; one action was overdue by more than 11 months; and one action was overdue by more than 1 year.

LASO assigned a CAP manager in February 2004. LASO established a Change Control Board process to manage changes to the CAP. LANL tracked the LASO corrective actions in the I-Track system. The CAP and change control actions associated with the CAP were provided to the Board by LASO.

The Board concluded that LASO's informal system for tracking issues arising from surveillance activities and the management of other corrective actions contributed to LASO's ineffective management of corrective actions associated with the August 5, 2003, Type B CAP that were assigned to LASO and NNSA.

LASO Oversight Staffing

The August 2005 LASO organization chart showed 17 personnel assigned to the Facility Representative (FR) Team. However, due to competing activities and priorities with the office, only four were working full time at their assigned facilities during the timeframe of the accident. LASO completed a staffing analysis and sent the results to NNSA Headquarters in January 2005. The results of the analysis showed the "effective" FR coverage was 5.5 FTEs. It stated: "LASO requires approximately 19 field deployed facility representative positions be staffed to ensure the 12 full time equivalent (FTE) FR coverage occurs in the most hazardous facilities. Two additional FR Team Leader positions were also required to provide day-to-day direction to the FRs." The staffing analysis was completed in accordance with guidance from NA-1, "Promulgation of Headquarters Guidance on Facility Representative Training and Facility Representative Staffing Analysis," sent October 13, 2004. At the time of the analysis, no FR staff was assigned duties at MST-6 (Sigma).

The limited Facility Representative and Safety and Health SME resources were recently aggravated by a rising number of competing priorities such as the recent LANL work suspension and resumption of activities for safety and security reasons; "Federalized" activities (a locally used term to indicate a high degree of Federal involvement to achieve Departmental priorities); and contract competition and selection activities. This has resulted in LASO focusing the FR coverage on the nuclear (higher hazard category) facilities and reduced oversight at less than hazard category 3 radiological facilities.

Oversight activities are accomplished at two levels. SMEs focus on assuring programmatic requirements are institutionally established and maintained, while the FRs focus on assuring that the programmatic requirements are implemented. LASO has only one SME to oversee the LANL radiation protection program. That SME is a Certified Health Physicist and carries the appropriate professional certifications, training, and experience to accomplish the assigned task. However, the programmatic responsibilities extend across the entire site, resulting in limited ability to provide comprehensive coverage to all facilities. The NNSA Service Center provides assistance, when requested, to conduct programmatic assessments as necessary.

The Board reviewed the last three years of radiological program assessments and found them to be comprehensive with regards to the areas evaluated. To augment his oversight activities, the radiation protection SME provides the FRs with comprehensive checklists that can be used to assess the effectiveness of the program implementation by LANL. However, none of the checklists have been filled out and returned to the SME.

The Board concluded that, given the limited SME availability, the lack of a FR assigned to Sigma, and the LASO focus on nuclear facilities, there has been no significant LASO presence in Sigma, or LASO awareness of the status of radiological operations in the facility, for the past few years.

As previously organized, the facilities operations staff of about 25 positions (FR and Safety and Health

SMEs) has seen a turnover of approximately 41 personnel in the last 10 years. The LASO office has had 18 managers in the last 20 years. The high turnover in personnel has resulted in challenges to LASO management in assuring sufficient, well qualified, and knowledgeable safety staff that is fully engaged in LANL oversight activities. LASO stated that they requested a staffing level increase from NNSA for FY-2006 from 111 FTEs to 180 FTEs. NNSA approved 129 FTEs. A breakdown by position was not immediately available. The Board requested and did not receive the attrition rates for the LASO office over the past ten years.

The Board concluded that since neither LANL's institutional assessment processes nor LASO's oversight efforts have focused on Sigma, there has been no viable external oversight of the facility for multiple years.

The Board concluded that the absence of LASO oversight and field presence in Sigma resulted in a lost opportunity for the NNSA to observe and assess the contractor's implementation and effectiveness of the IWM processes including the IWDs.

The Board also concluded that the lack of LANL and LASO oversight of Sigma likely contributed to the failure to identify and correct accepted practices and assumed requirements that had developed in the facility in conflict with the formally established requirements of LANL and DOE.

The NNSA expected LASO to provide the primary oversight of LANL. The NNSA program offices maintain a regular communication with LASO, but do not conduct any formal oversight of LASO to evaluate LASO's performance in overseeing LANL. The NNSA Administrator's Office, through the NNSA Chief of Defense Nuclear Safety, has recently started a process for periodically reviewing the oversight performance of all NNSA site offices, but these reviews are designed to focus primarily on nuclear facility safety oversight. The first NNSA review of LASO is not scheduled until next year.

The Board concluded that NNSA had failed to adequately evaluate LASO's oversight processes and their implementation.

Furthermore, the Board concluded that NNSA has failed to ensure that there is an adequate balance between LASO's responsibilities and LASO's resources for accomplishing those responsibilities.

Line and Independent Oversight and Enforcement Actions

LASO recently established an oversight schedule integrating LASO FR/SME and LANL oversight activities. The Integrated Oversight Schedule reviews the results of oversight activities by both LANL and LASO. It identified areas of weakness for upcoming oversight activities. LANL or LASO conducts the oversight based on area of organizational responsibility and the assessed weakness or need for improvement.

Annually, LASO appraises contractor performance in accordance with contract requirements. Specifically, Los Alamos National Laboratory Contract No. W-7405-ENG-36, Section H.007, *Performance-Based Management*, established Appendix F, *Standards for Performance.* Section H.007 required that "NNSA/DOE will use the Contractor's Evaluation Report as the primary basis for the annual appraisal of Contractor performance, recognizing that NNSA/DOE will take into account other pertinent information, including that performance against each Strategic Performance Objective is subject to timely availability of adequate funding, as well as operational oversight, internal and external program reviews and audits consistent with the intent of this Contract, in determining the annual appraisal for performance."

Modification M592 to the contract established the FY2004 Appendix F, Performance Objective #8 that contained measures to: "Maintain a secure, safe, environmentally sound, effective and efficient operations and infrastructure basis in support of mission objectives." LASO completed the FY2004 Annual Performance Appraisal of the University of California's Management and Operation of Los Alamos National Laboratory and concluded that all criteria in Section 8 rated UNSATISFACTORY performance. Subsequent to that rating, Modification M597 reduced the available Program Performance Fee by 51% for the FY 2004 evaluation period because of the performance failures.

In April 2003 and June 2004, NNSA, coordinating with the DOE Office of Price-Anderson Enforcement (OE), issued Preliminary Notice of Violation and Proposed Civil Penalties (PNOVs). The PNOVs assessed proposed civil penalties in the amounts of

$385,000 (waived by statute) and $770,000 (waived by statute) respectively against LANL. Relevant to this investigation, were the number of work control deficiencies identified in the OE report and cited in the PNOVs and the actions taken by NNSA.

The Board concluded that LASO was aware of the poor performance with regard to ISM implementation by LANL and took appropriate actions in accordance with the contract requirements. Additionally, NNSA recognized continuing issues related to the effective implementation of work controls requirements (e.g., ISM) and coordinated appropriate action with the Office of Enforcement.

FR Oversight Processes and Activities

The Board reviewed FR-generated surveillance reports from April 2003 to September 2005. Prior to the July 2004 work suspension, FR surveillance reports were compiled quarterly and sent to the contractor by formal letter. Beginning with the July 2004 work suspension, quarterly reports were no longer compiled by the FRs. No reports were compiled or forwarded to the contractor from about July 2004 until January 2005. In January 2005, LASO initiated a weekly reporting process for the FRs and SMEs. The FRs and SMEs completed a form electronically and forwarded it to the cognizant LANL Division Director (via e-mail) with a copy to the FR Team Lead (via e-mail).

The FR Team Lead compiled a roll-up report from the FR weekly reports. The roll-up report was sent to the Assistant Manager for Facility Operations, who highlighted significant issues or concerns and forwarded the report to other senior LASO and contractor management by e-mail. FRs and SMEs track their own findings and concerns as an individual effort. In the time period since April 2003, no surveillance activities were documented at Sigma.

DOE P 450.7, *Department Of Energy Environment, Safety and Health (ES&H) Goals*, requires that site-specific ES&H goals be established and approved by the Cognizant Secretarial Officer (CSO), and that progress against those measures be reported quarterly through the CSO to their Under Secretary. NNSA Deputy Director for Defense Programs issued a memorandum in December 2004 on NNSA ES&H performance data. That memorandum required the eight site offices to begin reporting ES&H data to Headquarters on a quarterly basis beginning with data collected during the first quarter of fiscal year 2005. Regardless, LASO has received no guidance from NNSA regarding the development of site-specific ES&H performance goals, LASO has not established or gained NNSA approval of site-specific ES&H goals. No quarterly reporting to NNSA is occurring for site-specific ES&H goals.

The Board concluded that NNSA has not provided adequate guidance to LASO regarding establishment and reporting of ES&H goals in accordance with DOE policy.

The Board is concerned that many of the weaknesses in oversight, on both the part of LANL and LASO, are likely to be equally or even more significant in non-radiological worker safety programs. Furthermore, the Board is concerned that NNSA's move toward hazard-based oversight has resulted in a focus on nuclear facilities and away from radiological and non-radiological worker safety. In contrast, the most consequential accidents in the DOE complex have been and continue to be in the area of non-radiological worker safety, such as falls, chemical exposures, and electrical hazards. Significant breakdowns in radiological worker safety controls that have resulted in multiple radiation exposures above Federal limits, and uncontrolled releases of radioactive material, such as in this accident, have also occured.

3.10 Events and Causal Factors, Barrier, and Change Analyses

Events and Causal Factors (ECF) Analysis is an accident investigation tool for depicting the logical sequence of events and conditions that allowed an accident to occur. This analysis begins with the development of an ECF chart, which is a timeline identifying the significant events in the order of their occurrence. The conditions that existed at the time of each event are also identified to the extent necessary. The results of the ECF chart are used in two ways. First, the timeline helps to guide the Board members in identifying particular aspects of the accident progression that require particular analytical focus; these are the areas evaluated in sections 3.1 through 3.9. Second, the ECF chart itself facilitates the use of deductive reasoning to determine which events and conditions contributed to the accident. The ECF chart is in Appendix B.

Barrier Analysis is an investigation tool that focuses on the various barriers that the Board believes should have helped to avoid or mitigate this accident. Barriers can be any feature such as physical structures, engineered controls, administrative controls, or worker training, that the Board determines should have affected the outcome of the sequence of events leading to the accident. The Barrier Analysis table is in Appendix C. The results of this analysis demonstrated that essentially all of the significant barriers in this accident either failed or were circumvented by the actions of the individuals involved.

Change Analysis is the third investigation tool used by this Board. By evaluating any changes that occurred in the process, workplace, or working environment during the sequence of events leading to the accident, the analysis determines if any of those changes had significant impact on the course of the events. Change Analysis can be conducted in either of two approaches. The first approach would be to evaluate actual changes that occurred during the timeline to understand their impacts. Alternatively, the second approach would be to consider the 'ideal' situation and to evaluate where the actual situation deviated from the ideal. In this investigation, the Board followed the first approach and evaluated changes in worker safety behavior, the pellet process, the transfer of the material and work between facilities, and job turnover between workers. The Board determined that changes in all of these areas had some impact on the events leading to the accident. In addition, the Board determined that all of these changes were influenced by latent conditions that preceded the events leading to the accident. The Change Analysis is in Appendix D.

4.0 Conclusions, Causes, and Judgments of Need

The Board determined that this accident occurred when highly contaminated parts, produced by NMT-11 in a glovebox in PF-4, were shipped to MST-6 in Sigma, and those parts were opened in a laser-welding glovebox with no radiological controls in place. Although NMT-11 suspected that the parts would likely be contaminated, they did not adequately convey that information to MST-6, and MST-6 did not proactively inquire about the radiological status of the parts. While NMT-11 suspected that the parts would be contaminated, they did not attempt to evaluate the contamination levels on the parts, so they had no appreciation for the significance of the contamination levels. As a consequence of the lack of knowledge and a complacent attitude on the part of the workers, the normal radiological controls at Sigma were all circumvented when the shipment arrived and was opened by the MST-6 employees. The release of the Am-241 contamination from the work area continued over the course of six workdays, eleven calendar days total, before a Sigma radiological control technician supervisor discovered it. During this time contamination was spread to multiple onsite locations, to four private residences in three states, and slightly contaminated parts were shipped to another NNSA facility in a fourth state. The primary individual involved also received an intake of Am-241 with a resulting radiation dose of about 500 millirem CEDE. The Board concluded that the repeated handling of highly contaminated materials without any radiological controls was the direct cause of this accident.

The work that was to be conducted with the parts at Sigma was a new activity that was not considered to be a major project, and therefore it had not received a significant level of safety review. The work at PF-4 was also a new project, but was very similar to other ongoing projects with more hazardous materials, and therefore NMT-11 did not consider the work to require any additional safety review beyond their previously reviewed and approved operating envelope. NMT-11 had frequently been shipping similar parts to other facilities that were accustomed to working with these highly contaminated parts, and therefore they assumed that MST-6 would be capable of handling the parts also. Therefore, the staffs of both facilities were performing within their normal modes of operations. The Board concluded that NMT-11's failure to adequately evaluate the potential for contamination on the parts and to communicate that information to MST-6 prior to shipping the parts was a root cause of this accident. The Board concluded that MST-6's failure to ensure that the radiological condition of the parts were evaluated, and to ensure that proper radiological controls were in place before accepting the shipment was also a root cause of this accident.

The Board concluded that multiple procedural failures occurred at both facilities during the conduct of this activity. Those failures resulted in an inadequate characterization of the radiological condition of the parts being shipped from PF-4 to Sigma; the improper receipt of the shipment at Sigma; the lack of awareness and involvement by the RCTs at Sigma; the opening of the shipment with no radiological controls; and multiple missed opportunities to avoid the accident or detect it at an early stage and thus effectively mitigate or avoid the consequences.

In evaluating those procedural failures, the Board concluded that essentially all were routine accepted practices at the facilities, and were therefore latent conditions. Furthermore, the Board identified a number of implied assumptions and assumed requirements that guided the behaviors of the workers and the design of the radiological controls at the facilities. The implied assumptions were never explicitly stated or verified and the assumed requirements conflicted with LANL's formally established requirements, thereby reducing the effectiveness of the institutional safety processes established by LANL. The Board concluded that these implied assumptions and assumed requirements were also latent conditions.

After concluding that all of the conditions that led to this accident were latent, the Board also concluded that most of those conditions could have readily been detected and corrected by an effective feedback and improvement or oversight program. The Board evaluated both the LANL and NNSA feedback and improvement processes and concluded that neither program had been effective in detecting most of the conditions. Those conditions that had been detected had not been effectively corrected. Therefore the

Board concluded that the failure of LANL and LASO's feedback and improvement programs was a third root cause for this accident.

Finally, the Board concluded that LASO was not receiving adequate guidance and direction from NNSA Headquarters for establishing oversight goals and priorities. At the same time, LASO was experiencing significant difficulties in attracting, maintaining, and qualifying personnel for safety-related positions. As a consequence, LASO had redirected essentially its entire safety-related staff to oversee the higher hazard nuclear facilities and some of the institutional programs that support those higher hazard nuclear facilities. LASO had expected that LANL's internal oversight programs would provide adequate coverage for the rest of the site, but LASO did not verify that those programs were adequate to accomplish that task. Therefore, Sigma and some aspects of the PF-4 operations had not received adequate oversight from either LANL or LASO for multiple years. The Board concluded that NNSA's failure to provide LASO with adequate guidance and direction to accomplish its oversight responsibilities, and to adequately oversee LASO's implementation of its oversight program to ensure that there was an adequate balance between NNSA expectations and LASO available resources, was a root cause for this accident.

After reviewing the onsite and offsite responses to this accident, the Board concluded that those responses provided adequate protection of the workers, the public, and the environment. The Board recognized that the urgency of the moment during such efforts would result in less than optimal formality in the command and control processes, in the criteria applied to various situations, and in the completeness and accuracy of the documentation. However, the Board believes that there are several lessons to be learned from this event that could improve the planning and preparation for similar future accidents, and therefore the Board has established four judgments of need that it believes will address those lessons learned.

Direct and Root Causes

Direct Cause: The Board concluded that the **direct cause** of this accident was the repeated handling of highly contaminated components with no radiological controls in place.

Root Cause 1: NMT-11 failed to evaluate the radiological contamination on the components, and failed to inform MST-6 of the potential for contamination, even though NMT-11 recognized that the possibility of contamination existed. The Board concluded that this failure was due to a latent condition that existed prior to the onset of the events leading to this accident.

Root Cause 2: MST-6 failed to ensure that the radiological condition of the components was fully evaluated, and that proper radiological controls were in place, before accepting the components and commencing work with them. The Board concluded that this failure was due to a latent condition that existed prior to the onset of the events leading to this accident.

Root Cause 3: LANL and LASO failed to adequately oversee NMT, MST, and HSR, allowing the latent conditions that were the root causes of this accident to become established without detection and correction.

Root Cause 4: NNSA failed to ensure that LASO had adequate guidance and direction to accomplish its oversight responsibilities, and failed to adequately oversee LASO's implementation of its oversight program to ensure that there was an adequate balance between NNSA expectations and LASO's available resources.

Judgments of Need

Part 1: These Judgments of Need address the causal factors of the accident.

<table>
<tr><th>Judgment of Need</th><th>Supporting Discussion</th></tr>
<tr><td>LANL needs to review the Integrated Work Management processes and the associated guidance and implementation to ensure that:

❑ Projects that cross organizational boundaries are controlled such that hazards inherent in the work are consistently communicated between and understood by all involved groups;
❑ The IWM processes are consistently and uniformly applied throughout the institution, across organizational boundaries;
❑ IWD developers, users, and Persons-in-Charge are properly trained in accordance with LANL policies <u>before</u> they can be authorized to perform those functions; and
❑ Periodic institutional and organizational assessments are conducted to evaluate the consistency and effectiveness of the implementation of the IWM processes at the working level.</td><td>NMT-11 did not clearly communicate to MST-6 all of the hazards associated with the material being transferred to Sigma.

NMT-11 assumed that since the work to be done at Sigma was in a glovebox, the parts would not need to be decontaminated before transfer to MST-6. MST-6 assumed that the parts being transferred from PF-4 would be decontaminated before transfer. Neither group verified their assumptions.

MST mistakenly believed that they had received a waiver from all of the required LANL IWM training modules.

The IWM policy does not clearly define when an IWD is necessary for working with radioactive material, resulting in inconsistent applications.

The Board identified a recurring pattern of inadequate implementation of the IWM process and appropriate control procedures by MST-6.

The Board identified multiple accepted practices, at both Sigma and PF-4, which were inconsistent with the intent of the IWM policy and LANL requirements.

The Board identified multiple assumed requirements that were inconsistent with established LANL requirements.</td></tr>
<tr><td>LANL needs to develop, implement, and validate effective internal assessment, audit, assurance, and corrective action processes to ensure that work is being conducted in accordance with LANL, DOE, and Federal requirements, and that issues identified are aggressively and effectively corrected.</td><td>Receipt inspections of radioactive material shipments were not routinely performed at Sigma.

Radioactive material shipments from PF-4 were not routinely evaluated and labeled in accordance with LANL requirements and local procedures.

Workers at Sigma did not demonstrate an adequate and consistent understanding of how to respond to contamination monitor alarms.</td></tr>
</table>

Judgment of Need	Supporting Discussion
	The Board identified a recurring pattern of inadequate implementation of the IWM process and appropriate control procedures by MST-6. The Board identified multiple accepted practices, at both Sigma and PF-4, which were inconsistent with the intent of the IWM policy and LANL requirements. The Board identified multiple assumed requirements that were inconsistent with established LANL requirements. The receipt of the shipment and removal of the TIDs were not conducted in accordance with LANL MCA requirements. The Board concluded that all procedural non-adherences involved in this accident were latent conditions that existed prior to the onset of the events leading to this accident. The Board determined that several of the accepted practices and latent conditions involved in this accident had been previously identified by LANL, but had not been effectively corrected.
LANL needs to charter a comprehensive external assessment of the LANL radiation protection program to determine the extent of the condition of programmatic concerns identified during this investigation. This assessment needs to, at a minimum, address the following concerns: ❑ Adequacy of the technical bases for the implementation of operational requirements, such as selection of instruments, posting of areas, workplace monitoring processes, and consistency with facility's authorized limits; ❑ Adequacy of staffing and funding levels for supporting normal operations and providing subject matter expertise to line organizations; ❑ Adequacy of contingencies for supplemental support for off-normal and emergency operations;	PF-4 RCTs did not follow established procedures for evaluating the radioactive material to be transferred to Sigma. Shipping documents were routinely not completed at PF-4 in accordance with LANL procedures. The Board concluded there was inadequate RCT staffing at Sigma to effectively implement a radiation protection program for normal operations at the facility. The Board was concerned that HSR-1 staffing shortfalls may extend to other LANL facilities as well. At Sigma, RCT support is not routinely requested through the established management system but is informally and verbally requested for immediate response.

Judgment of Need	Supporting Discussion
❑ Adequacy and effectiveness of radiation worker training provided to general employees; ❑ Adequacy, effectiveness, and timeliness of corrective actions taken in response to radiation protection–related issues identified in internal and external audits and assessments; ❑ Adequacy and quality of records and documentation used to demonstrate compliance with LANL and DOE requirements; and ❑ Adequacy of the level of procedure adherence among the radiological control technicians and program staff. This assessment should focus adequate attention on radiological facilities (less-than-category-3 nuclear facilities) to ensure that the evaluation provides a balanced view of the overall health of the program.	Sigma workers routinely did not notify the Sigma RCTs of incoming radioactive material shipments. Working with radioactive material without notifying RCTs had become an accepted practice at Sigma. Receipt inspections for radioactive material shipments were not routinely conducted at Sigma. Sigma workers responded to a contamination alarm incorrectly and did not notify the RCTs of the event. The contamination at Sigma was not detected by routine workplace monitoring processes. Sigma RCTs were not familiar with the capabilities of the instrumentation in the facility. Contamination control and posting criteria used at Sigma were not consistent with DOE requirements. During recovery operations, there was difficulty in obtaining and retaining supplemental RCT support from other LANL facilities. Building survey documents contained numerous errors and omissions, and could not demonstrate the adequacy of the evaluation and cleanup of the Sigma building.
NMT needs to: ❑ Review PF-4 policies and procedures to ensure that radiological hazards associated with materials being removed from PF-4 and transferred to other organizations are fully evaluated and documented; ❑ Establish processes by which those radiological hazards are adequately communicated to the receiving organization; and	NMT-11 did not clearly communicate to MST-6 all of the hazards associated with the material being transferred to Sigma. PF-4 RCTs did not follow established procedures for evaluating the radioactive material to be transferred to Sigma. Shipping documents were routinely not completed at PF-4 in accordance with LANL procedures. The Board identified multiple accepted practices, at both Sigma and PF-4, which were inconsistent with the intent of the IWM policy and LANL requirements.

Judgment of Need	Supporting Discussion
❑ Incorporate into their assessment processes mechanisms to ensure that facility records are periodically audited to ensure compliance with these facility procedures and LANL policies and requirements.	Radioactive material shipments from PF-4 were not routinely evaluated and labeled in accordance with LANL requirements and local procedures.
MST needs to: ❑ Ensure that the LANL IWM policy is fully incorporated and implemented for all Division activities; ❑ Develop and implement line management assessment processes that periodically evaluate the effectiveness of the Division's IWM processes; ❑ Establish mechanisms to routinely monitor the level of compliance with these IWM processes at MST facilities; and ❑ Aggressively and proactively work with the MST staff to improve the level of formality and rigor applied to the IWM processes at Sigma.	MST workers had not received the required training in the LANL IWM process before performing roles as IWD developer, user, and PIC for IWDs developed under the IWM process. The receipt, inspection, and opening of the shipment from PF-4 were not evaluated as work activities within the IWD developed for the uranium nitride pellet encapsulation project at Sigma. The Board identified a recurring pattern of inadequate implementation of the IWM process and appropriate control procedures by MST-6. MST workers did not always have the required training and qualifications for work they were assigned, and those requirements were not verified.
MST needs to proactively address issues identified in previous assessments in a more timely and aggressive manner to improve the formality of operations at Sigma.	The Board concluded that some accepted practices at Sigma had been previously detected but had not been effectively corrected. MST's Resumption MSA corrective actions extend to August 2007, and include actions such as: develop and implement a 10 CFR 830.120 quality assurance program by Sept. 2006; develop and implement a self-assessment program for MST by Oct. 2006; develop and implement process for annual review of worker training plans by Aug. 2007; and develop a worker qualification process/ program based on IWD requirements by Aug. 2007.

Judgment of Need	Supporting Discussion
MST needs to work with HSR to ensure that: ❑ The LANL radiation protection program is fully implemented and adequately staffed at Sigma; ❑ There is an adequate and documented technical basis for the program, consistent with the facility's authorized limits. ❑ The radiation protection program requirements are formally established and appropriately communicated to workers; and ❑ Adherence to those requirements is regularly assessed.	The Board concluded that there was inadequate RCT staffing at Sigma to effectively implement a radiation protection program for normal operations at the facility. At Sigma, RCT support is not routinely requested through the established management system but is informally and verbally requested for immediate response. Sigma workers routinely did not notify the Sigma RCTs of incoming radioactive material shipments. Working with radioactive material without notifying RCTs had become an accepted practice at Sigma. Receipt inspections for radioactive material shipments were not routinely conducted at Sigma. Sigma workers responded to a contamination alarm incorrectly and did not notify the RCTs of the event. This incorrect response was found to be a routine accepted practice at Sigma. The Board identified multiple accepted practices and assumed requirements at Sigma that were inconsistent with LANL requirements, policies, and training for work involving radioactive materials. The contamination at Sigma was not detected by routine workplace monitoring processes. Sigma RCTs were not familiar with the capabilities of the instrumentation in the facility. Contamination control and posting criteria used at Sigma were not consistent with DOE requirements.
HSR-1 needs to ensure that radiation protection staff and RCTs assigned to various facilities are regularly sharing information regarding radioactive material and radiological work that is being transferred between facilities.	The Sigma RCTs were not routinely notified of incoming radioactive material shipments by facility staff. Working with radioactive material without notifying RCTs had become an accepted practice at Sigma.

Judgment of Need	Supporting Discussion
HSR-1 and SUP-5 need to develop and implement a mechanism by which HSR-1 personnel are directly notified by SUP-5 of incoming radioactive material shipments that are destined for facilities under their cognizance.	The Sigma RCTs were not routinely notified of incoming radioactive material shipments by facility staff. Receipt inspections for radioactive material shipments were not routinely conducted at Sigma.
LASO needs to expand its operational oversight programs to encompass Sigma and other facilities conducting radiological work at less-than-category-3 levels, to ensure that LANL institutional work control and worker protection programs are adequately implemented and properly maintained.	The Board identified multiple accepted practices that were causal factors in this accident. The Board concluded that all of the casual factors leading to this accident were latent conditions that had existed and gone undetected or uncorrected prior to the onset of the events leading to this accident. The Board concluded that, given limited SME availability, no assigned Facility Representative, and the LASO focus on higher hazard nuclear facilities, that there had been no LASO presence in Sigma for the past few years.
LASO needs to manage findings from FR surveillances, assessments, and previous accident investigations in a manner that assures timely and effective completion and validation of corrective actions.	The Board concluded that all of the casual factors leading to this accident were latent conditions that had existed and gone undetected or uncorrected prior to the onset of the events leading to this accident. The Board concluded that several of the latent conditions involved in this accident had been previously identified but had not been effectively corrected.
LASO needs to verify that LANL's internal assessment, audit, assurance, and corrective action processes are robust, rigorous, and capable of ensuring that work is being conducted in accordance with LANL, DOE, and Federal requirements, and that issues identified are aggressively and effectively corrected.	The Board concluded that the failure of the combined LANL and LASO oversight processes were a root cause of this accident in that all of the causal factors were latent conditions that existed prior to the onset of the events leading to this accident.

Judgment of Need	Supporting Discussion
NNSA needs to formally establish oversight expectations and guidance for LASO, ensure that there is a balance between those expectations and LASO's available resources, and periodically assess LASO's performance in meeting those expectations.	LASO has been unable to obtain and retain sufficient numbers of qualified personnel to maintain allotted staffing levels, and staffing analyses show that higher staffing levels may be necessary to fully accomplish oversight mission. NNSA has not provided adequate guidance to LASO regarding the establishment and reporting of ES&H goals in accordance with DOE policy.

These Judgements of Need address the lessons learned from the response activities.

Judgment of Need	Supporting Discussion
LANL needs to review the lessons learned from this accident and incorporate them into the LANL emergency management program to ensure that adequate plans and preparations exist for a large-scale loss of control of hazardous material event such as this one.	The Board concluded that the ad hoc management team and command and control structure established to respond to this accident did not have sufficient resources and processes to adequately manage the necessary efforts. The Board evaluated LANL's Incident Command System and concluded that many of the Board's concerns with the onsite response activities would have been addressed had this system been activated. The activation of the Incident Command System would have provided leadership, formality, decision-making processes, and resources that are designed for and experienced in responding to hazardous materials accidents.
LASO needs to define resource requirements for mitigating offsite impacts from normal and emergency operations at LANL, and as part of a comprehensive emergency management program LASO needs to define their role in coordinating overall implementation of command, control, and communication functions.	LASO does not have a support agreement in place with the DOE RAP program to cover LANL's participation in the program or LASO's missions at Los Alamos. LASO has not adequately addressed DOE's offsite emergency response requirements.
NNSA needs to improve coordination between NA-40 and NA-10 to ensure that the NNSA line managers are adequately engaged in the process when a NA-40 emergency response asset is responding to a request involving a NA-10 facility or site.	NA-10 was not engaged in decisions regarding NA-40 activities in response to an event under NA-10's cognizance.

Judgment of Need	Supporting Discussion
NNSA/NA-40 needs to review the lessons learned from this accident for incorporation into its emergency response plans, and needs to consider providing technically-based "default" radiological release criteria to the RAP program for use in the response when DOE is the cognizant agency or where there is no other authority having jurisdiction.	The RAP teams used incorrect radiological release criteria and had no pre-established criteria or guidance.

5.0 Board Signatures

Douglas M. Minnema

Date 11/22/05

Douglas M. Minnema, Ph.D., CHP, Chairperson
DOE Accident Investigation Board
National Nuclear Security Administration

Date 11/22/05

Milton W. Chilton, CHP, Member
DOE Accident Investigation Board
National Nuclear Security Administration
NNSA Service Center

Ronald V. Fontana

Date 11/22/05

Ronald V. Fontana, Member
DOE Accident Investigation Board
National Nuclear Security Administration
Los Alamos Site Office

David A. Hall

Date 11/22/05

David A. Hall, Member
DOE Accident Investigation Board
National Nuclear Security Administration
NNSA Service Center

6.0 Board Members, Advisors, and Staff

Board Chair	Douglas M. Minnema, Ph.D., Certified Health Physicist NNSA Office of the Senior Advisor for ES&H
Member	Milton W. Chilton, Certified Health Physicist NNSA Service Center, Environment, Safety, and Health Department
Member	Ronald V. Fontana, Facility Representative NNSA Los Alamos Site Office
Member	David A. Hall, Health Physicist NNSA Service Center, Environment, Safety, and Health Department
Advisors	William C. McQuiston DOE Idaho Operations Office, Facility and Operations Assurance Program Frederick J. Bell Los Alamos Site Office
Laboratory Observer	Matthew W. Hardy LANL Performance Surety Division, Operational Assurance Group
Technical Advisor	M. Bradford Graves, Certified Health Physicist BWXT Y-12 National Nuclear Security Complex
Technical Writers	Alice Morris, SAIC Robin Phillips, SAIC
Administration	Sandra Robinson, SAIC
Publication	Daniel Gagne, SAIC

Appendix A - Letter of Appointment

UNITED STATES GOVERNMENT | DEPARTMENT OF ENERGY

memorandum

National Nuclear Security Administration
Los Alamos Site Office
Los Alamos, New Mexico 87544

DATE: AUG 15 2005
REPLY TO ATTN OF: OFO:8KK-024
SUBJECT: Type B Investigation – Americium-241 Contamination Event at TA-3-SM-66R3 and Release to On- and Off-site Locations

TO: Douglas M. Minnema, PhD, CHP, Board Chairperson, NA-1. HQ/FORS

I hereby establish a Type B Accident Investigation Board to investigate the contamination incident that occurred at the Los Alamos National Laboratory's TA-3-SM-66R3, and was discovered on July 25, 2005. I have determined that it meets the requirements established in DOE Order 225.1A, "Accident Investigations" dated November 26,1997, for a Type B Accident Investigation Board.

I appoint you as the Board Chairperson. The team will consist of:

<u>Board Members:</u>
David Hall, NNSA Service Center
Milton Chilton, NNSA Service Center
Ron Fontana, LASO

<u>Trained Investigator:</u>
David Hall

Advisors, consultants, and other support personnel as determined by the chairperson will assist the Board.

The Board will be chartered for a time-period of August 15, 2005, to September 30, 2005. In the event that the Board cannot conclude its investigation by September 30, 2005, the investigation will be extended until the Board's investigation is complete.

The scope of the Board's investigation will include, but is not limited to, identifying all relevant facts; analyzing the facts to determine the direct, contributing, and root causes of the accident; developing conclusions; and determining the judgments of need that, when implemented, should prevent the recurrence of the accident. The investigation will be conducted in accordance with Department of Energy (DOE) Order 225.1A and will specifically address the role of DOE, contractor organizations, and management systems as they may have contributed to the accident. The scope will also include the actions taken by LANL and DOE in response to the discovery of the incident, including the deployment of Radiological Assistance Program (RAP) assets to off-site locations,

NNSA/DOE
Los Alamos Site Office
528 35th Street
Los Alamos, NM 87544-2201

NNSA/DOE
Headquarters
1000 Independence Avenue, SW
Washington, DC 20585-1290

AUG 15 2005

any deficiencies related to Integrated Safety Management System implementation, and the application of lessons learned from similar accidents within DOE.

The Board will provide my office with periodic reports on the status of the investigation but will not include any conclusions until an analysis of all of the causal factors has been completed. Draft copies of the factual portion of the investigation report will be submitted to DOE and the Los Alamos National Laboratory for a factual accuracy review prior to report finalization.

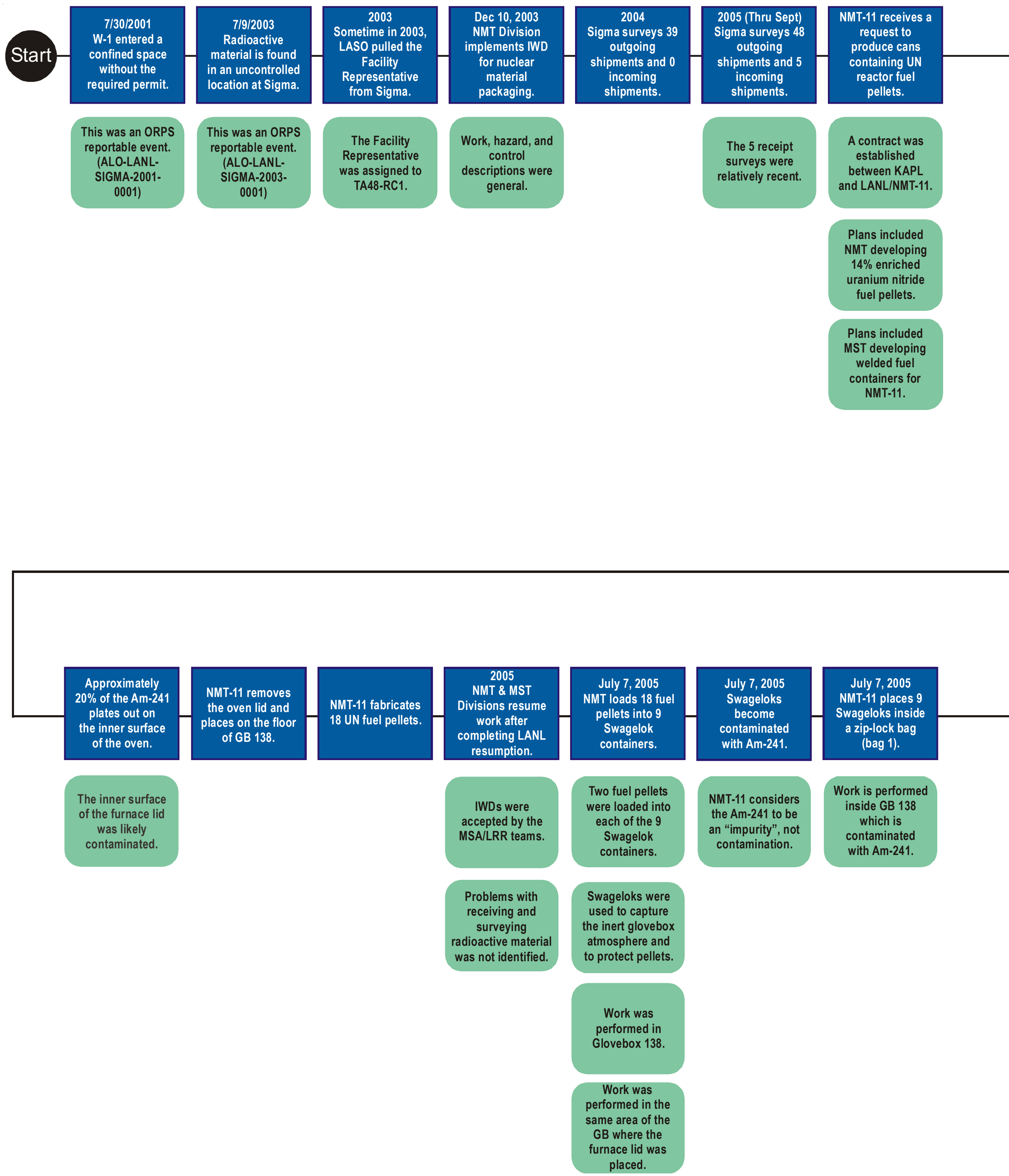
This report should be provided to me for acceptance by September 30, 2005. Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report.

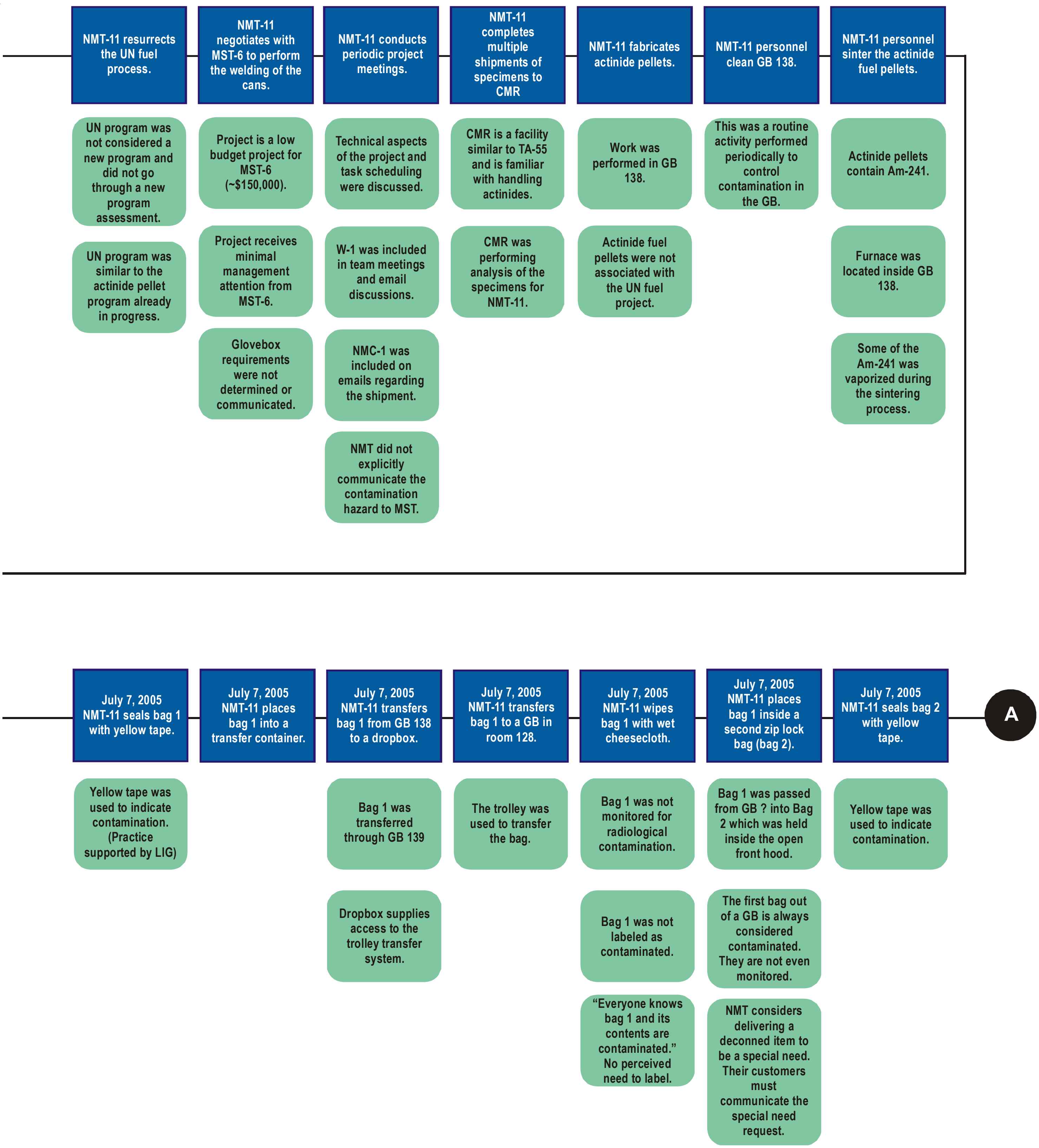
Edwin L. Wilmot
Manager

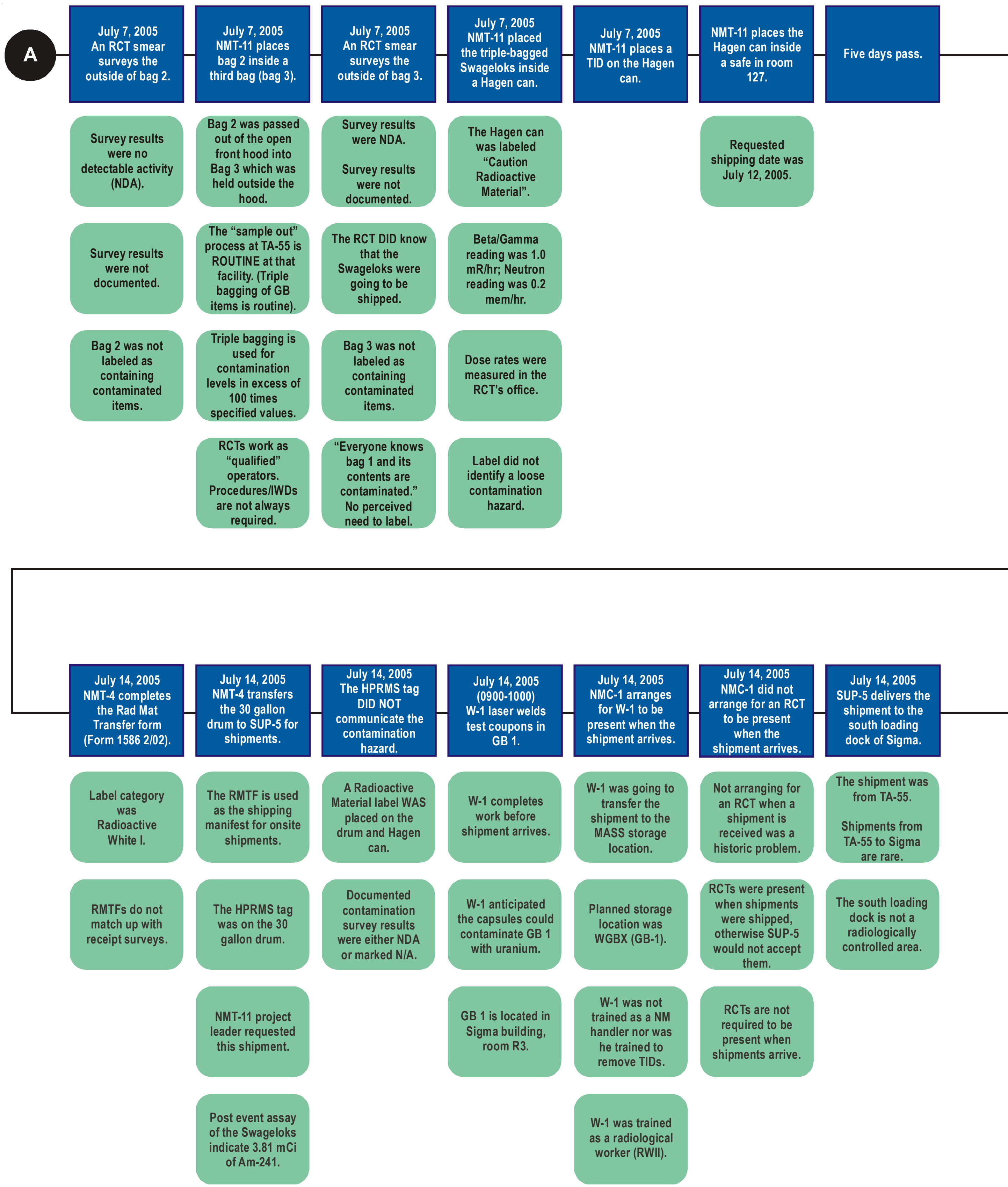
cc:
E. Morrow, NA-1, HQ/FORS
J. McConnell, NA-1, HQ/FORS
T. D'Agostino, NA-10, HQ/FORS
D. Minnema, NA-1, HQ/GTN
D. Harvey, NA-1, HQ/FORS
J. Chavez-Wilcynski, OOM, LASO
G. Schlapper, SSA, LASO
R. Corman, OC, LASO
C. Crooks, BA, LASO
A. Lovato, BA, LASO
K. Keilholtz, AMFO, LASO
J. Pugh, OFO, LASO
E. Christie OFO, LASO
C. Keilers, DNFSB, LASO
D. Cobb, DIR, LANL, MS-A100
R. Lemons, ADSR, LANL, MS-A127
C. Mangeng, ADTS, LANL, MS-A104
J. Angelo, PS-DO, LANL, MS-C347
P. Follansbee, MST-DO, LANL, MS-G754
V. Majidi, C-DO, LANL, MS-J515
W. Wadt, PCO, LANL, MS-M722

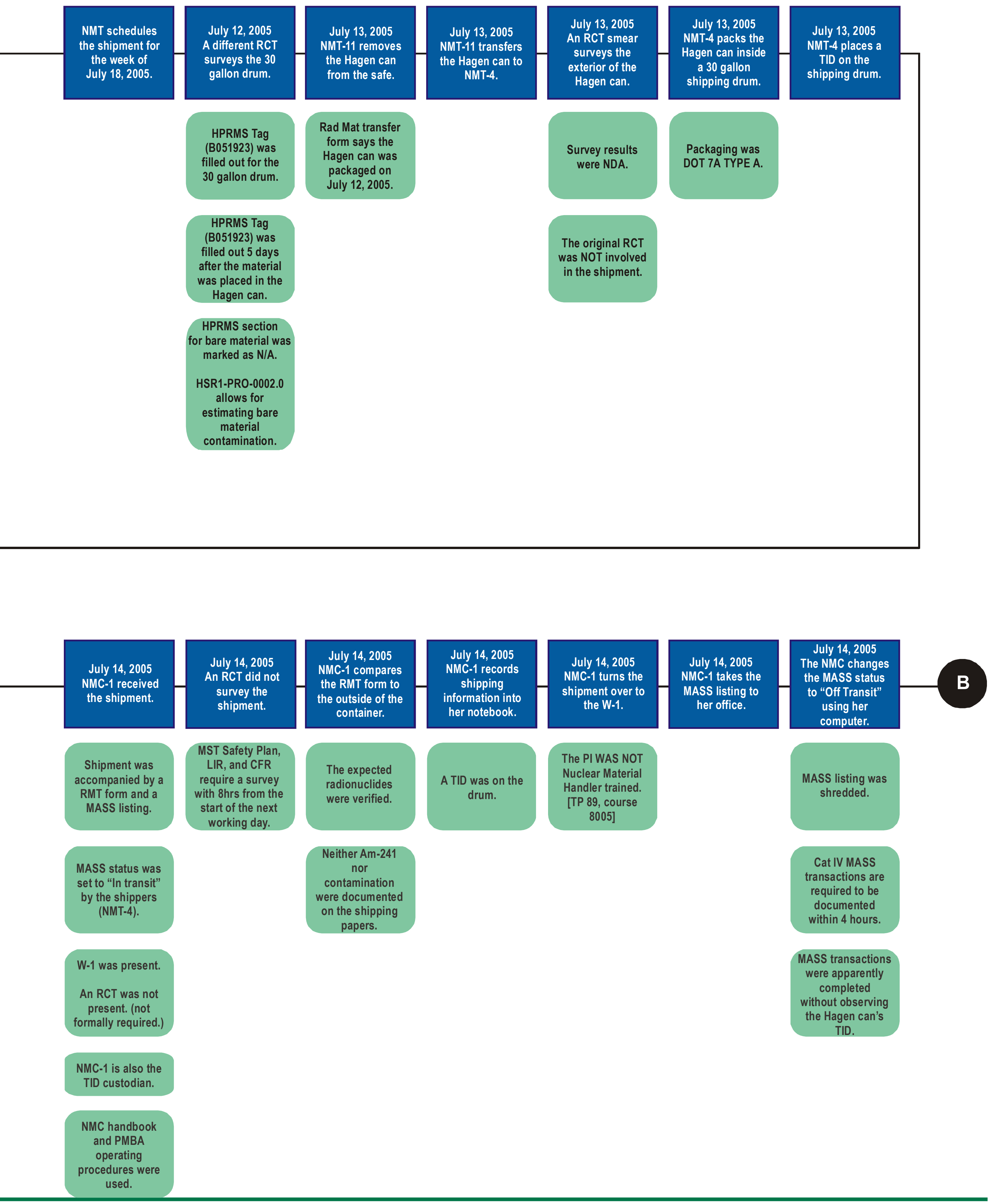
Appendix B - Events and Causal Factors Chart

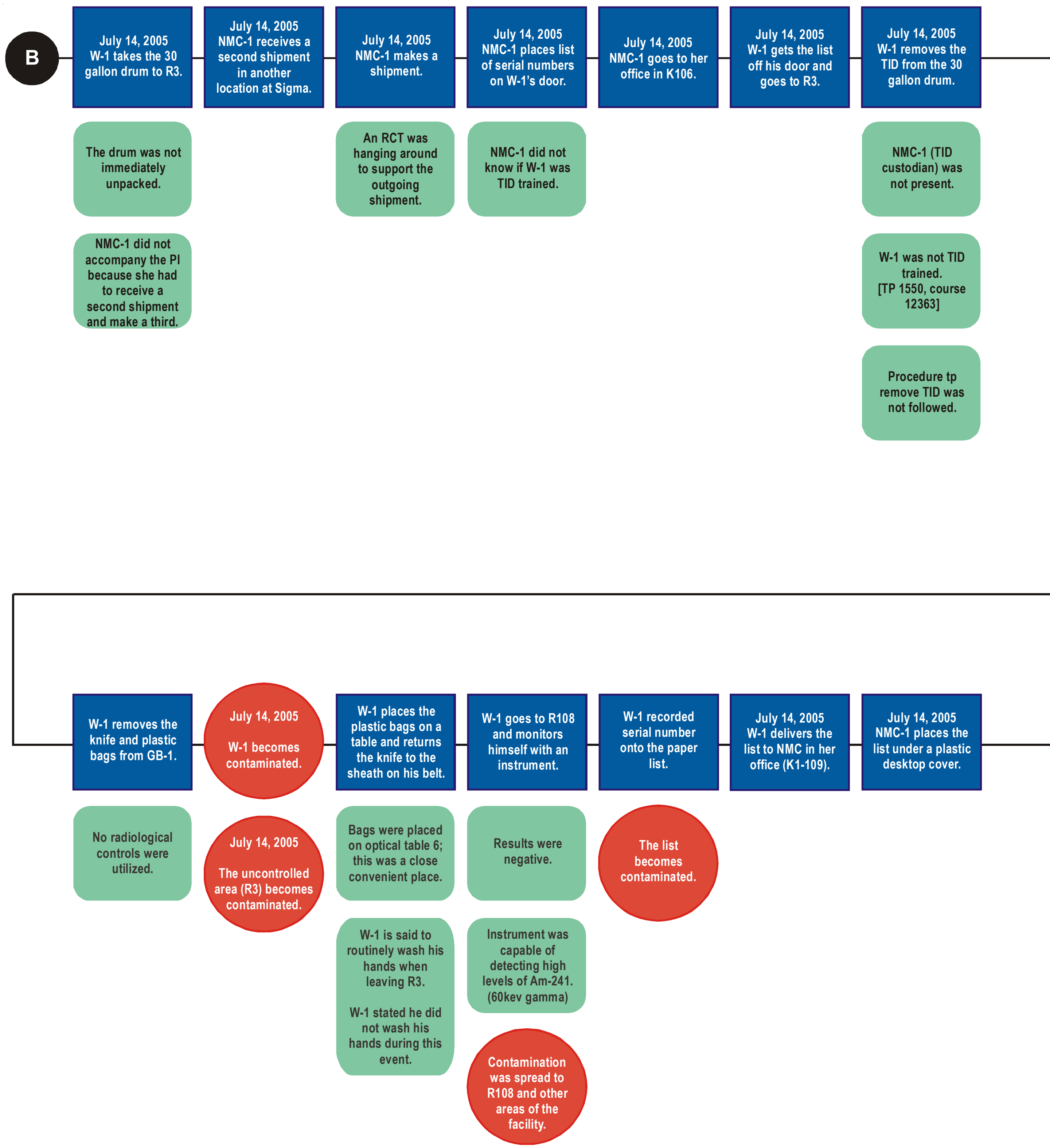
The Events and Causal Factors Chart begins on the following page.

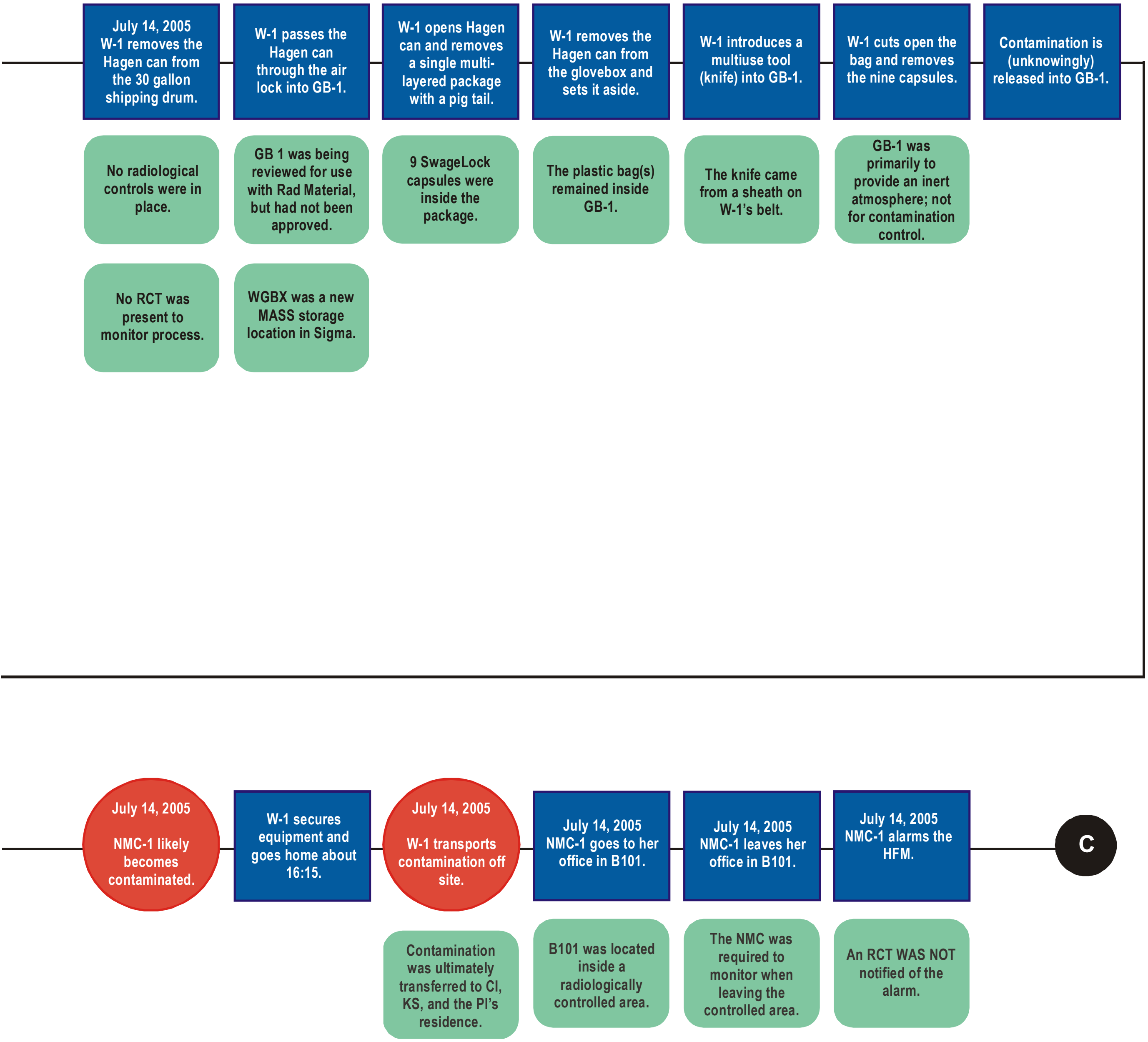

Start
7/30/2001 W-1 entered a confined space without the required permit.
This was an ORPS reportable event. (ALO-LANL-SIGMA-2001-0001)
7/9/2003 Radioactive material is found in an uncontrolled location at Sigma.
This was an ORPS reportable event. (ALO-LANL-SIGMA-2003-0001)
2003 Sometime in 2003, LASO pulled the Facility Representative from Sigma.
The Facility Representative was assigned to TA48-RC1.
Dec 10, 2003 NMT Division implements IWD for nuclear material packaging.
Work, hazard, and control descriptions were general.
2004 Sigma surveys 39 outgoing shipments and 0 incoming shipments.
2005 (Thru Sept) Sigma surveys 48 outgoing shipments and 5 incoming shipments.
The 5 receipt surveys were relatively recent.
NMT-11 receives a request to produce cans containing UN reactor fuel pellets.
A contract was established between KAPL and LANL/NMT-11.
Plans included NMT developing 14% enriched uranium nitride fuel pellets.
Plans included MST developing welded fuel containers for NMT-11.
Approximately 20% of the Am-241 plates out on the inner surface of the oven.
The inner surface of the furnace lid was likely contaminated.
NMT-11 removes the oven lid and places on the floor of GB 138.
NMT-11 fabricates 18 UN fuel pellets.
2005 NMT & MST Divisions resume work after completing LANL resumption.
IWDs were accepted by the MSA/LRR teams.
Problems with receiving and surveying radioactive material was not identified.
July 7, 2005 NMT loads 18 fuel pellets into 9 Swagelok containers.
Two fuel pellets were loaded into each of the 9 Swagelok containers.
Swageloks were used to capture the inert glovebox atmosphere and to protect pellets.
Work was performed in Glovebox 138.
Work was performed in the same area of the GB where the furnace lid was placed.
July 7, 2005 Swageloks become contaminated with Am-241.
NMT-11 considers the Am-241 to be an “impurity”, not contamination.
July 7, 2005 NMT-11 places 9 Swageloks inside a zip-lock bag (bag 1).
Work is performed inside GB 138 which is contaminated with Am-241.

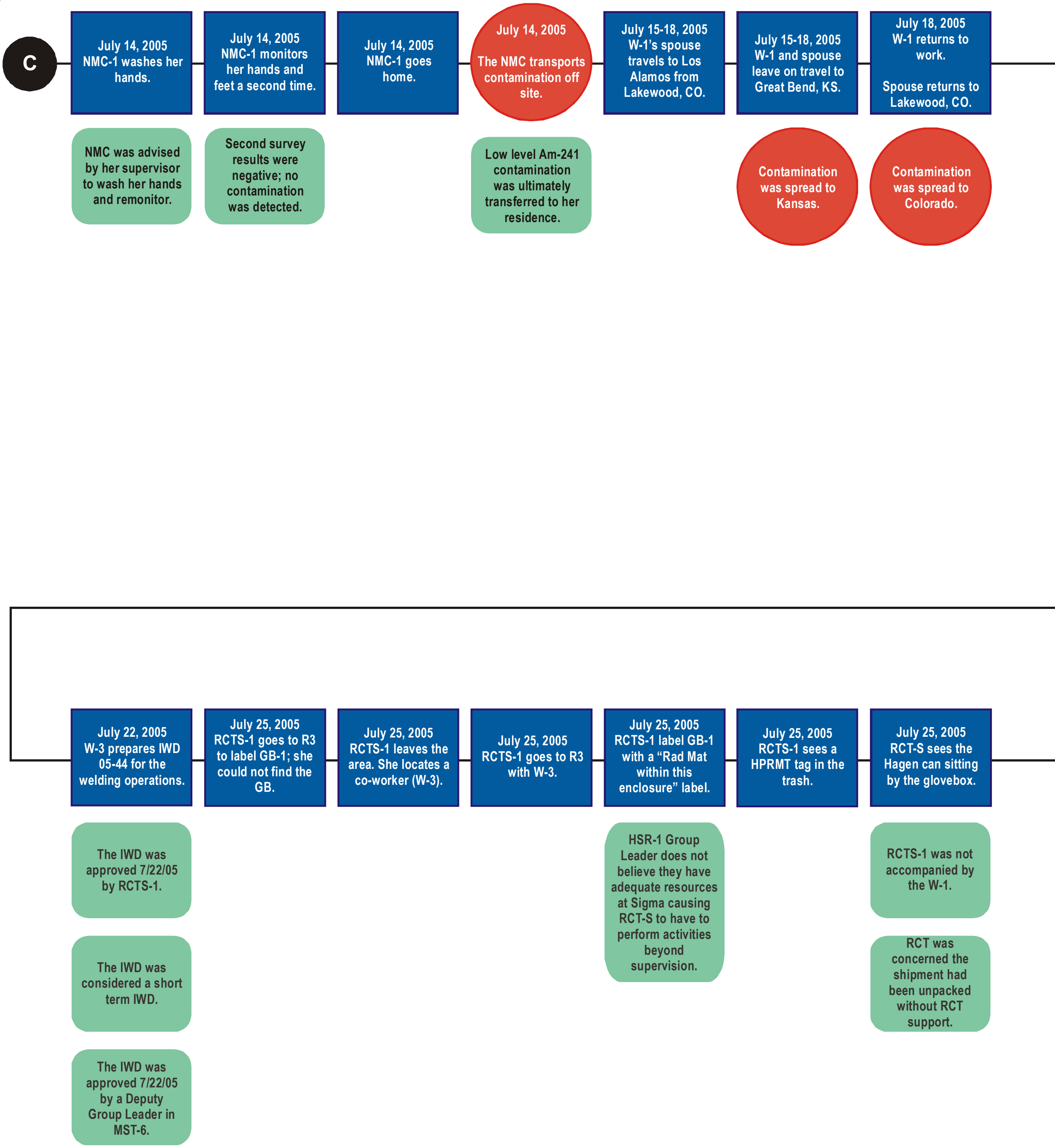

NMT-11 resurrects the UN fuel process.
UN program was not considered a new program and did not go through a new program assessment.
UN program was similar to the actinide pellet program already in progress.
NMT-11 negotiates with MST-6 to perform the welding of the cans.
Project is a low budget project for MST-6 (~$150,000).
Project receives minimal management attention from MST-6.
Glovebox requirements were not determined or communicated.
NMT-11 conducts periodic project meetings.
Technical aspects of the project and task scheduling were discussed.
W-1 was included in team meetings and email discussions.
NMC-1 was included on emails regarding the shipment.
NMT did not explicitly communicate the contamination hazard to MST.
NMT-11 completes multiple shipments of specimens to CMR
CMR is a facility similar to TA-55 and is familiar with handling actinides.
CMR was performing analysis of the specimens for NMT-11.
NMT-11 fabricates actinide pellets.
Work was performed in GB 138.
Actinide fuel pellets were not associated with the UN fuel project.
NMT-11 personnel clean GB 138.
This was a routine activity performed periodically to control contamination in the GB.
NMT-11 personnel sinter the actinide fuel pellets.
Actinide pellets contain Am-241.
Furnace was located inside GB 138.
Some of the Am-241 was vaporized during the sintering process.
July 7, 2005 NMT-11 seals bag 1 with yellow tape.
Yellow tape was used to indicate contamination. (Practice supported by LIG)
July 7, 2005 NMT-11 places bag 1 into a transfer container.
July 7, 2005 NMT-11 transfers bag 1 from GB 138 to a dropbox.
Bag 1 was transferred through GB 139
Dropbox supplies access to the trolley transfer system.
July 7, 2005 NMT-11 transfers bag 1 to a GB in room 128.
The trolley was used to transfer the bag.
July 7, 2005 NMT-11 wipes bag 1 with wet cheesecloth.
Bag 1 was not monitored for radiological contamination.
Bag 1 was not labeled as contaminated.
“Everyone knows bag 1 and its contents are contaminated.” No perceived need to label.
July 7, 2005 NMT-11 places bag 1 inside a second zip lock bag (bag 2).
Bag 1 was passed from GB ? into Bag 2 which was held inside the open front hood.
The first bag out of a GB is always considered contaminated. They are not even monitored.
NMT considers delivering a deconned item to be a special need. Their customers must communicate the special need request.
July 7, 2005 NMT-11 seals bag 2 with yellow tape.
Yellow tape was used to indicate contamination.
A

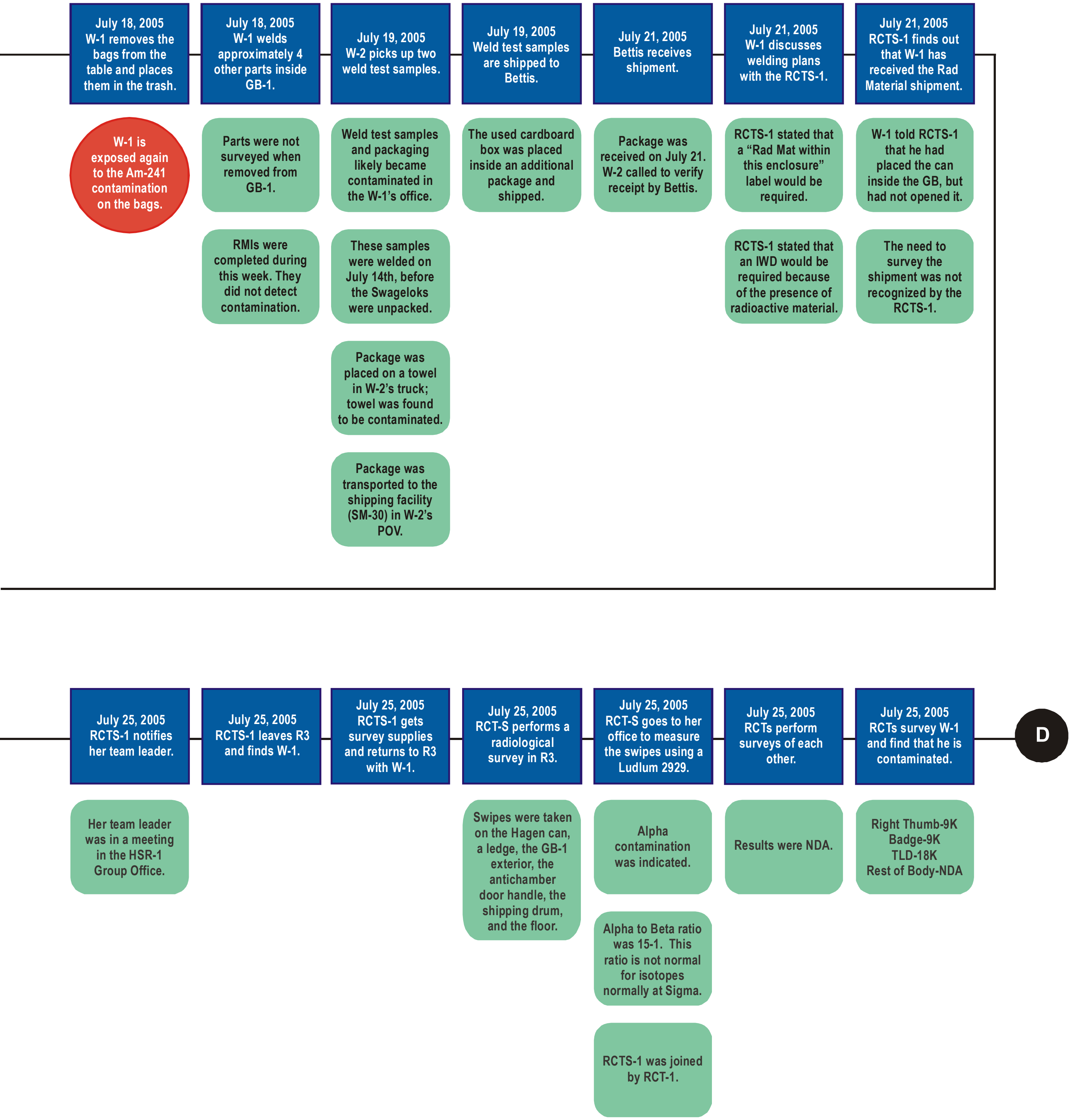

A
July 7, 2005 An RCT smear surveys the outside of bag 2.
Survey results were no detectable activity (NDA).
Survey results were not documented.
Bag 2 was not labeled as containing contaminated items.
July 7, 2005 NMT-11 places bag 2 inside a third bag (bag 3).
Bag 2 was passed out of the open front hood into Bag 3 which was held outside the hood.
The “sample out” process at TA-55 is ROUTINE at that facility. (Triple bagging of GB items is routine).
Triple bagging is used for contamination levels in excess of 100 times specified values.
RCTs work as “qualified” operators. Procedures/IWDs are not always required.
July 7, 2005 An RCT smear surveys the outside of bag 3.
Survey results were NDA. Survey results were not documented.
The RCT DID know that the Swageloks were going to be shipped.
Bag 3 was not labeled as containing contaminated items.
“Everyone knows bag 1 and its contents are contaminated.” No perceived need to label.
July 7, 2005 NMT-11 placed the triple-bagged Swageloks inside a Hagen can.
The Hagen can was labeled “Caution Radioactive Material”.
Beta/Gamma reading was 1.0 mR/hr; Neutron reading was 0.2 mem/hr.
Dose rates were measured in the RCT’s office.
Label did not identify a loose contamination hazard.
July 7, 2005 NMT-11 places a TID on the Hagen can.
NMT-11 places the Hagen can inside a safe in room 127.
Requested shipping date was July 12, 2005.
Five days pass.
July 14, 2005 NMT-4 completes the Rad Mat Transfer form (Form 1586 2/02).
Label category was Radioactive White I.
RMTFs do not match up with receipt surveys.
July 14, 2005 NMT-4 transfers the 30 gallon drum to SUP-5 for shipments.
The RMTF is used as the shipping manifest for onsite shipments.
The HPRMS tag was on the 30 gallon drum.
NMT-11 project leader requested this shipment.
Post event assay of the Swageloks indicate 3.81 mCi of Am-241.
July 14, 2005 The HPRMS tag DID NOT communicate the contamination hazard.
A Radioactive Material label WAS placed on the drum and Hagen can.
Documented contamination survey results were either NDA or marked N/A.
July 14, 2005 (0900-1000) W-1 laser welds test coupons in GB 1.
W-1 completes work before shipment arrives.
W-1 anticipated the capsules could contaminate GB 1 with uranium.
GB 1 is located in Sigma building, room R3.
July 14, 2005 NMC-1 arranges for W-1 to be present when the shipment arrives.
W-1 was going to transfer the shipment to the MASS storage location.
Planned storage location was WGBX (GB-1).
W-1 was not trained as a NM handler nor was he trained to remove TIDs.
W-1 was trained as a radiological worker (RWII).
July 14, 2005 NMC-1 did not arrange for an RCT to be present when the shipment arrives.
Not arranging for an RCT when a shipment is received was a historic problem.
RCTs were present when shipments were shipped, otherwise SUP-5 would not accept them.
RCTs are not required to be present when shipments arrive.
July 14, 2005 SUP-5 delivers the shipment to the south loading dock of Sigma.
The shipment was from TA-55. Shipments from TA-55 to Sigma are rare.
The south loading dock is not a radiologically controlled area.

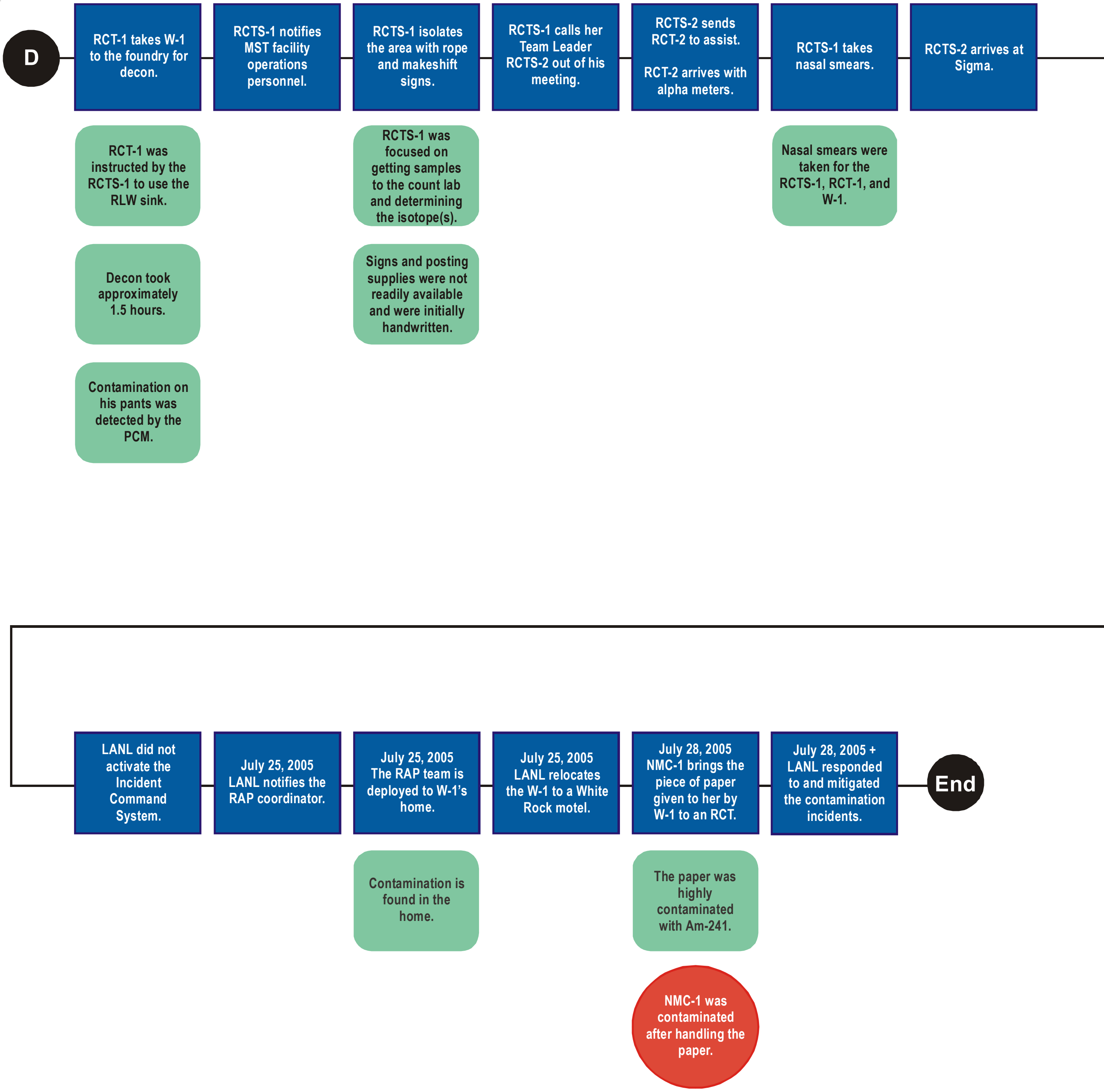

NMT schedules the shipment for the week of July 18, 2005.
July 12, 2005 A different RCT surveys the 30 gallon drum.
HPRMS Tag (B051923) was filled out for the 30 gallon drum.
HPRMS Tag (B051923) was filled out 5 days after the material was placed in the Hagen can.
HPRMS section for bare material was marked as N/A.
HSR1-PRO-0002.0 allows for estimating bare material contamination.
July 13, 2005 NMT-11 removes the Hagen can from the safe.
Rad Mat transfer form says the Hagen can was packaged on July 12, 2005.
July 13, 2005 NMT-11 transfers the Hagen can to NMT-4.
July 13, 2005 An RCT smear surveys the exterior of the Hagen can.
Survey results were NDA.
The original RCT was NOT involved in the shipment.
July 13, 2005 NMT-4 packs the Hagen can inside a 30 gallon shipping drum.
Packaging was DOT 7A TYPE A.
July 13, 2005 NMT-4 places a TID on the shipping drum.
July 14, 2005 NMC-1 received the shipment.
Shipment was accompanied by a RMT form and a MASS listing.
MASS status was set to “In transit” by the shippers (NMT-4).
W-1 was present.
An RCT was not present. (not formally required.)
NMC-1 is also the TID custodian.
NMC handbook and PMBA operating procedures were used.
July 14, 2005 An RCT did not survey the shipment.
MST Safety Plan, LIR, and CFR require a survey with 8hrs from the start of the next working day.
July 14, 2005 NMC-1 compares the RMT form to the outside of the container.
The expected radionuclides were verified.
Neither Am-241 nor contamination were documented on the shipping papers.
July 14, 2005 NMC-1 records shipping information into her notebook.
A TID was on the drum.
July 14, 2005 NMC-1 turns the shipment over to the W-1.
The PI WAS NOT Nuclear Material Handler trained. [TP 89, course 8005]
July 14, 2005 NMC-1 takes the MASS listing to her office.
July 14, 2005 The NMC changes the MASS status to “Off Transit” using her computer.
MASS listing was shredded.
Cat IV MASS transactions are required to be documented within 4 hours.
MASS transactions were apparently completed without observing the Hagen can’s TID.
B

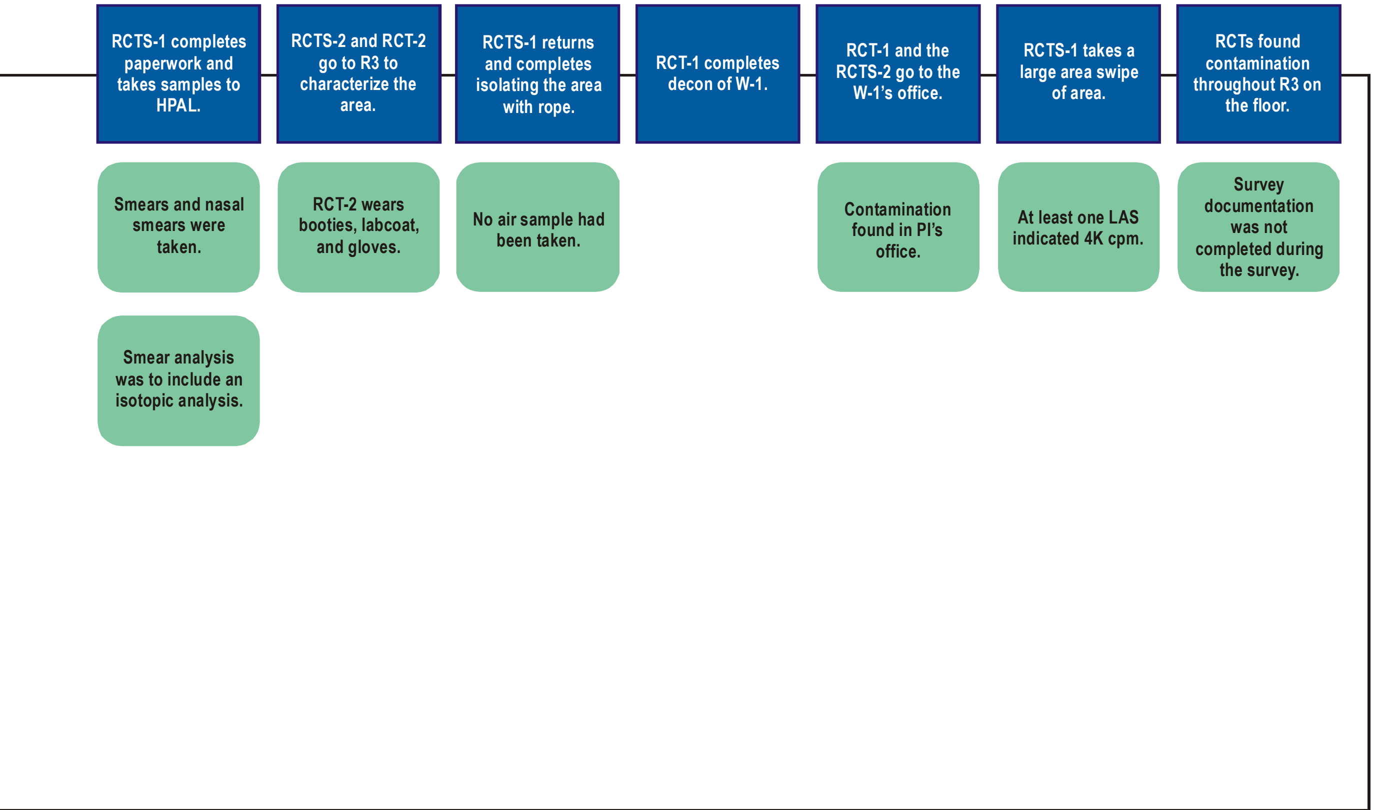

B
July 14, 2005 W-1 takes the 30 gallon drum to R3.
July 14, 2005 NMC-1 receives a second shipment in another location at Sigma.
July 14, 2005 NMC-1 makes a shipment.
July 14, 2005 NMC-1 places list of serial numbers on W-1's door.
July 14, 2005 NMC-1 goes to her office in K106.
July 14, 2005 W-1 gets the list off his door and goes to R3.
July 14, 2005 W-1 removes the TID from the 30 gallon drum.
The drum was not immediately unpacked.
NMC-1 did not accompany the PI because she had to receive a second shipment and make a third.
An RCT was hanging around to support the outgoing shipment.
NMC-1 did not know if W-1 was TID trained.
NMC-1 (TID custodian) was not present.
W-1 was not TID trained. [TP 1550, course 12363]
Procedure tp remove TID was not followed.
W-1 removes the knife and plastic bags from GB-1.
July 14, 2005 W-1 becomes contaminated.
W-1 places the plastic bags on a table and returns the knife to the sheath on his belt.
W-1 goes to R108 and monitors himself with an instrument.
W-1 recorded serial number onto the paper list.
July 14, 2005 W-1 delivers the list to NMC in her office (K1-109).
July 14, 2005 NMC-1 places the list under a plastic desktop cover.
No radiological controls were utilized.
July 14, 2005 The uncontrolled area (R3) becomes contaminated.
Bags were placed on optical table 6; this was a close convenient place.
Results were negative.
The list becomes contaminated.
W-1 is said to routinely wash his hands when leaving R3.
W-1 stated he did not wash his hands during this event.
Instrument was capable of detecting high levels of Am-241. (60kev gamma)
Contamination was spread to R108 and other areas of the facility.


July 14, 2005 W-1 removes the Hagen can from the 30 gallon shipping drum.
W-1 passes the Hagen can through the air lock into GB-1.
W-1 opens Hagen can and removes a single multi-layered package with a pig tail.
W-1 removes the Hagen can from the glovebox and sets it aside.
W-1 introduces a multiuse tool (knife) into GB-1.
W-1 cuts open the bag and removes the nine capsules.
Contamination is (unknowingly) released into GB-1.
No radiological controls were in place.
GB 1 was being reviewed for use with Rad Material, but had not been approved.
9 SwageLock capsules were inside the package.
The plastic bag(s) remained inside GB-1.
The knife came from a sheath on W-1's belt.
GB-1 was primarily to provide an inert atmosphere; not for contamination control.
No RCT was present to monitor process.
WGBX was a new MASS storage location in Sigma.
July 14, 2005 NMC-1 likely becomes contaminated.
W-1 secures equipment and goes home about 16:15.
July 14, 2005 W-1 transports contamination off site.
July 14, 2005 NMC-1 goes to her office in B101.
July 14, 2005 NMC-1 leaves her office in B101.
July 14, 2005 NMC-1 alarms the HFM.
C
Contamination was ultimately transferred to CI, KS, and the PI's residence.
B101 was located inside a radiologically controlled area.
The NMC was required to monitor when leaving the controlled area.
An RCT WAS NOT notified of the alarm.


C
July 14, 2005
NMC-1 washes her hands.
NMC was advised by her supervisor to wash her hands and remonitor.
July 14, 2005
NMC-1 monitors her hands and feet a second time.
Second survey results were negative; no contamination was detected.
July 14, 2005
NMC-1 goes home.
July 14, 2005
The NMC transports contamination off site.
Low level Am-241 contamination was ultimately transferred to her residence.
July 15-18, 2005
W-1's spouse travels to Los Alamos from Lakewood, CO.
July 15-18, 2005
W-1 and spouse leave on travel to Great Bend, KS.
Contamination was spread to Kansas.
July 18, 2005
W-1 returns to work.
Spouse returns to Lakewood, CO.
Contamination was spread to Colorado.
July 22, 2005
W-3 prepares IWD 05-44 for the welding operations.
The IWD was approved 7/22/05 by RCTS-1.
The IWD was considered a short term IWD.
The IWD was approved 7/22/05 by a Deputy Group Leader in MST-6.
July 25, 2005
RCTS-1 goes to R3 to label GB-1; she could not find the GB.
July 25, 2005
RCTS-1 leaves the area. She locates a co-worker (W-3).
July 25, 2005
RCTS-1 goes to R3 with W-3.
July 25, 2005
RCTS-1 label GB-1 with a "Rad Mat within this enclosure" label.
HSR-1 Group Leader does not believe they have adequate resources at Sigma causing RCT-S to have to perform activities beyond supervision.
July 25, 2005
RCTS-1 sees a HPRMT tag in the trash.
July 25, 2005
RCT-S sees the Hagen can sitting by the glovebox.
RCTS-1 was not accompanied by the W-1.
RCT was concerned the shipment had been unpacked without RCT support.


July 18, 2005 W-1 removes the bags from the table and places them in the trash.
W-1 is exposed again to the Am-241 contamination on the bags.
July 18, 2005 W-1 welds approximately 4 other parts inside GB-1.
Parts were not surveyed when removed from GB-1.
RMIs were completed during this week. They did not detect contamination.
July 19, 2005 W-2 picks up two weld test samples.
Weld test samples and packaging likely became contaminated in the W-1's office.
These samples were welded on July 14th, before the Swageloks were unpacked.
Package was placed on a towel in W-2's truck; towel was found to be contaminated.
Package was transported to the shipping facility (SM-30) in W-2's POV.
July 19, 2005 Weld test samples are shipped to Bettis.
The used cardboard box was placed inside an additional package and shipped.
July 21, 2005 Bettis receives shipment.
Package was received on July 21. W-2 called to verify receipt by Bettis.
July 21, 2005 W-1 discusses welding plans with the RCTS-1.
RCTS-1 stated that a "Rad Mat within this enclosure" label would be required.
RCTS-1 stated that an IWD would be required because of the presence of radioactive material.
July 21, 2005 RCTS-1 finds out that W-1 has received the Rad Material shipment.
W-1 told RCTS-1 that he had placed the can inside the GB, but had not opened it.
The need to survey the shipment was not recognized by the RCTS-1.
July 25, 2005 RCTS-1 notifies her team leader.
Her team leader was in a meeting in the HSR-1 Group Office.
July 25, 2005 RCTS-1 leaves R3 and finds W-1.
July 25, 2005 RCTS-1 gets survey supplies and returns to R3 with W-1.
July 25, 2005 RCT-S performs a radiological survey in R3.
Swipes were taken on the Hagen can, a ledge, the GB-1 exterior, the antichamber door handle, the shipping drum, and the floor.
July 25, 2005 RCT-S goes to her office to measure the swipes using a Ludlum 2929.
Alpha contamination was indicated.
Alpha to Beta ratio was 15-1. This ratio is not normal for isotopes normally at Sigma.
RCTS-1 was joined by RCT-1.
July 25, 2005 RCTs perform surveys of each other.
Results were NDA.
July 25, 2005 RCTs survey W-1 and find that he is contaminated.
Right Thumb-9K
Badge-9K
TLD-18K
Rest of Body-NDA
D


D
RCT-1 takes W-1 to the foundry for decon.
RCT-1 was instructed by the RCTS-1 to use the RLW sink.
Decon took approximately 1.5 hours.
Contamination on his pants was detected by the PCM.
RCTS-1 notifies MST facility operations personnel.
RCTS-1 isolates the area with rope and makeshift signs.
RCTS-1 was focused on getting samples to the count lab and determining the isotope(s).
Signs and posting supplies were not readily available and were initially handwritten.
RCTS-1 calls her Team Leader RCTS-2 out of his meeting.
RCTS-2 sends RCT-2 to assist.
RCT-2 arrives with alpha meters.
RCTS-1 takes nasal smears.
Nasal smears were taken for the RCTS-1, RCT-1, and W-1.
RCTS-2 arrives at Sigma.
LANL did not activate the Incident Command System.
July 25, 2005 LANL notifies the RAP coordinator.
July 25, 2005 The RAP team is deployed to W-1's home.
Contamination is found in the home.
July 25, 2005 LANL relocates the W-1 to a White Rock motel.
July 28, 2005 NMC-1 brings the piece of paper given to her by W-1 to an RCT.
The paper was highly contaminated with Am-241.
NMC-1 was contaminated after handling the paper.
July 28, 2005 + LANL responded to and mitigated the contamination incidents.
End


RCTS-1 completes paperwork and takes samples to HPAL.
Smears and nasal smears were taken.
Smear analysis was to include an isotopic analysis.
RCTS-2 and RCT-2 go to R3 to characterize the area.
RCT-2 wears booties, labcoat, and gloves.
RCTS-1 returns and completes isolating the area with rope.
No air sample had been taken.
RCT-1 completes decon of W-1.
RCT-1 and the RCTS-2 go to the W-1's office.
Contamination found in PI's office.
RCTS-1 takes a large area swipe of area.
At least one LAS indicated 4K cpm.
RCTs found contamination throughout R3 on the floor.
Survey documentation was not completed during the survey.

Appendix C - Barrier Chart

Barrier	Target	Function	Causal
IWM	PI	NMT IWD for packaging and shipping NM did not identify or control the contamination hazard to the receiver (in this case MST-6).	Yes
	PI, Sigma occupants	JIMO project leader did not ensure that the glovebox at Sigma was adequate for the known actinide contamination hazard.	Yes
Receipt Survey	PI and/or workers in the facility.	Receipt surveys were not routinely performed on shipments received by MST-6.	Yes
Management Oversight	PI	Management did not ensure the worker was qualified.	Yes
	Workers	Management systems did not detect and correct longstanding procedural non-compliances such as not surveying radioactive material received into the building.	Yes
	Workers	LASO did not provide sufficient oversight of Sigma operations. The Facility Representative was reassigned to another facility and the oversight presence was not adequate for Sigma. LASO also did not validate LANL's oversight processes before relying on them.	Yes
Resumption Review Process	NMT & MST Divisions	IWDs for both NMT and MST were reviewed and accepted by the resumption process	No
	Personnel receiving shipments	Receipt of radioactive material shipments was not reviewed during resumption.	Yes

Barrier	Target	Function	Causal
Labeling of Radioactive Material	PI	Yellow tape was used to seal the plastic bags in pigtail arrangement.	No
	PI	Bags were not labeled as containing contaminated items.	Yes
	PI	The Hagen can was labeled as containing Radioactive Material but did not identify the contamination hazard inside.	Yes
Triple bagging for containment	PI	The 9 Swageloks were placed inside 3 successive bags to contain the contamination.	No
Tamper Indicating Device (TID)	Nuclear Material	A TID was placed on both the Hagen can and the 30-gal. Shipping drum. Two qualified people are required to be present when the TID is removed.	No, but could have caused a second person to be involved when the Hagen can was opened. This second person could have altered the course of events.
Health Physics Radioactive Material Survey (HPRMS)	PI, NMC	An HPRMS tag was placed on the 30-gal drum. The HPRMS tag did not identify the contamination hazard inside the plastic bags. Bare material survey data was marked NA. Procedure allows for estimating bare material contamination.	Yes
Training of personnel	PI	The PI was not trained to handle nuclear material.	Yes
	PI	The PI was not trained to remove TIDs.	Yes
	PI	The PI was trained as a Radiological Worker (RWII).	No

Barrier	Target	Function	Causal
Procedures not established or not used by workers	General Safety of Workers	Not having an RCT present is normal practice. Received shipments are rarely, if ever, surveyed. NMC did not arrange for an RCT to be present when the shipment arrived. Received shipments are required to be surveyed within 8 hours beginning the next working day after the receipt.	Yes
Radiological controls	PI, NMC, Building occupants	An RCT was never notified and therefore did not survey the shipment after receipt.	Yes
		An RCT was not present when the shipment was unpacked nor when the Hagen can was opened.	Yes
		Glovebox was outside established radiological control areas, no personnel contamination monitoring in place.	Yes
Glovebox	PI, Room occupants	Primary purpose is to maintain an inert atmosphere for welding.	No
		Contamination control procedures were not implemented. This allowed items to be taken out of the glovebox without being monitored.	Yes
Personnel Monitoring	Co-workers, building, public	The PI either did not detect contamination when he monitored with a hand frisker in R108 or he did not respond properly when he detected contamination. Contamination levels were most likely sufficient to be detected, if present.	Maybe (It is possible that PI had monitored before removing material from glovebox; sequence could not be determined exactly.)

Barrier	Target	Function	Causal
	Co-workers, building, public	NMC did not respond properly to an HFM alarm.	Yes
Radiological Surveillance	Sigma building occupants	Daily and weekly RMIs did not detect the contamination.	Yes

Appendix D - Change Chart

Change	Description	Effect	Causal
PI's behavior did not change.	The PI's behavior in this event parallels behavior observed when he entered a confined space in 2001 without the required permit.	Corrective Actions for 2001 event were not effective in changing the PI's behavior. Actions included disciplinary actions.	Yes
		Director's Instruction during resumption process did not ensure the PI and NMC were sufficiently committed to working in a compliant and safe manner.	Yes
		Involved RLMs and TL did not provide oversight of the workers or the project. Undesirable behaviors and practices were allowed to exist in the workplace.	Yes
TA-55 (NMT-4) shipped to Sigma.	TA-55 had been shipping samples to another LANL nuclear facility (CMR), which handled actinide-contaminated items routinely. Sigma is a radiological facility, which is not accustomed to handling actinides.	Actinides are common at both TA-55 and CMR. Personnel who work at TA-55 and CMR implicitly know and understand the hazards. Sigma personnel do not necessarily know nor recognize actinides and their hazards.	Yes
NMT-11 changed between the actinide and UN processes being conducted in GB-138.	NMT-11 personnel would alternate between fabricating actinide pellets as well as UN pellets inside the same glovebox.	The actinide process was the major source of the Am-241 contamination on the UN pellet packaging.	Yes
		The glovebox is cleaned when switching from one process to the other. However, the Swageloks® were loaded after the actinide process restarted.	Yes

Change	Description	Effect	Causal
RCT support changed individuals.	RCT who supported the shipment was not the same RCT who was involved in the sample out and packaging of the Swageloks® inside the Hagen can.	The RCT who surveyed and tagged the drum for shipment did not have direct knowledge of the radiological condition of the items inside the Hagen can, yet he filled out the HPRMS tag.	Maybe
Change in custody of material.	Custody was changed form NMT-11 to NMT-4. Custody changed from NMT-4 to SUP-5. Custody changed from SUP-5 to MST-6.	The Swageloks® were transferred from the programmatic group (NMT-11) to the shipping group with NMT (NMT-4) to the transportation group (SUP-5) to the receiving group (MST-6). Hazard information was not adequately conveyed between groups.	Yes

Acronyms

CAM	Continuous Air Monitor
CEDE	Committed Effective Dose Equivalent
CFR	Code of Federal Regulations
CSO	Cognizant Secreterial Officer
DAC	Derived Air Concentration
DOE	Department of Energy
DOT	Department of Transportation
DP	Defense Programs
ECF	Events and Causal Factors
EM&R	Emergency Management and Response
ERO	Emergency Response Organization
ES&H	Environment, Safety and Health
F&I (FI)	Feedback and Improvement
FR	Facility Representative
FSA	Facility Safety Analysis
FSP	Facility Safety Plan
HEPA	High Efficiency Particulate Aerosol
HPAL	Health Physics Analytical Laboratory
HSR	Health, Safety, and Radiation Protection
IMP	Implementation Procedure
ISM	Integrated Safety Management
IWD	Integrated Work Document
IWM	Integrated Work Management
JHA	Job Hazard Analysis
JON	Judgment of Need
LANL	Los Alamos National Laboratory
LASO	Los Alamos Site Office
LRR	Laboratory Resumption Review
MBA	Mass Balance Area
MASS	Material Accountability Security System
MC&A (MCA)	material control and accountability
MSA	Management Self-Assessment
MST	Materials Science and Technology
NDA	nondestructive assay
NMC	Nuclear Material Custodian
NMT	Nuclear Materials Technology
NNSA	National Nuclear Security Administration
OE	Office of Price Anderson Enforcement
ORPS	Occurrence Reporting and Processing System
P&T	Packaging and Transportation
PF	Plutonium Facility
PIC	Person In Charge
PIO	Public Information Officer
POV	personally owned vehicle
RAP	Radiological Assistance Program
RCT	Radiological Control Technician
RCTS	Radiological Control Technician Supervisor
RDL	Responsible Division Leader
RLM	Responsible Line Manager
RPP	Radiological Protection Program
RPPM	Radiation Protection Program Manager
RWP	Radiological Work Permit
S&H	Safety and Health
SME	Subject Matter Expert
TA	Technical Area
TID	Tamper Indicating Device
UC	University of California
WSS	Work Smart Standards