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SC&A Review of Remaining Internal Dose Issues for the LANL SEC-0109 Addendum Period (1996–2000)

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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
Ac	actinium
Am	americium
BEST	Bioassay Enrollment, Scheduling, and Tracking (system)
CAM	continuous air monitor
CEDE	committed effective dose equivalent
Cf	californium
CFR	Code of Federal Regulations
Ci	curie
Cm	curium
CMR	Chemistry and Metallurgy Research
Co	cobalt
cpm	counts per minute
Cs	cesium
DAC	derived air concentration
DOE	U.S. Department of Energy
DOELAP	Department of Energy Laboratory Accreditation Program
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
dpm/cm^2	disintegrations per minute per square centimeter
dpm/m^3	disintegrations per minute per cubic meter
DPVP	Dosimetry Participation Verification Program
DR	dose reconstruction
EE	energy employee
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
ER	evaluation report
ESH	Environmental Safety and Health
FWO	Facility and Waste Operations
g	gram
H-3, ^3H	tritium
He	helium
HEPA	high-efficiency particulate air (filter)

Hf	hafnium
HP	health physics
HPC	health physics checklist
I	iodine
IDEP	internal dose evaluation program
Ir	iridium
JCNNM	Johnson Controls Northern New Mexico
LAAO	Los Alamos Area Office
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
Lu	lutetium
MAP	mixed activation product
mCi	millicurie
MFAP	mixed fission and activation product
MFP	mixed fission product
mg	milligram
Mg	magnesium
Mn	manganese
mrem	millirem
mrem/yr	millirem per year
$\mu Ci/m^3$	microcuries per cubic meter
Na	sodium
NA	not applicable
Nd	neodymium
NDA	no detectable activity
NIOSH	National Institute for Occupational Safety and Health
NMT	Nuclear Materials Technology
Np	neptunium
NTS	Noncompliance Tracking System (DOE)
ORAU	Oak Ridge Associated Universities
ORAUT	Oak Ridge Associated Universities Team
ORPS	Occurrence Reporting and Processing System
Pa	protactinium

PAL	plutonium access list
pCi	picocurie
PMR	palladium membrane reactor
Pu	plutonium
RAS	radiometric alpha spectrometry
RBA	radiological buffer area
RCT	radiological control technician
RMI	routine monitoring instruction
RPP	radiation protection program
RSS	Radiation Security System
RWP	radiological work permit
SEC	Special Exposure Cohort
SEM	scanning electron microscope
Sr	strontium
SRDB	Site Research Database
SRS	Savannah River Site
STC	special tritium compound
Ta	tantalum
TA	technical area
TBD	technical basis document
Th	thorium
TIMS	thermal ionization mass spectroscopy
TIP	technical issue paper
Tl	thallium
TPE	Tritium Plasma Experiment
TPOP	Tritium Proof of Principle (experiment)
TWOPOS	time-weighted one-person-one-statistic
U	uranium
V	vanadium
WBC	whole-body count
Y	yttrium

Executive Summary

At the July 25, 2019, meeting of the Los Alamos National Laboratory (LANL) Work Group, the National Institute for Occupational Safety and Health (NIOSH) acknowledged that SC&A "disagrees with NIOSH's assessment that the amount of routine bioassay data available obviates the need to confirm its completeness in the face of NC ID 484 findings [of] potential data gaps for bioassay enrollment and RWP [radiological work permit] job-specific bioassay participation" and recommended that "NIOSH follow up with LANL to ascertain whether the bioassay incompleteness identified in the limited sampling in 1999 reflects a broader incompleteness in LANL's bioassay database for 1996-2000" (NIOSH, 2019b, slide 3). However, a joint interview with knowledgeable LANL staff determined that "There was nothing done at the time to determine the magnitude of individuals not leaving the required bioassay" (NIOSH, 2019b, slide 4). For other issues (such as inadequacies in workers completing RWP-related checklists), corrective actions were taken to remedy monitoring program shortcomings only going forward. NIOSH acknowledged that a "similar situation occurred during the SRS [Savannah River Site] evaluation" for questions about the completeness of RWP-directed job-specific bioassays and that "in order to resolve that issue, NIOSH agreed to develop a sampling plan and sample RWP's to determine compliance with bioassay requirements" (NIOSH, 2019b, slide 5). For the other Special Exposure Cohort (SEC)-related issue involving mixed fission and activation products (i.e., "exotics"), NIOSH proposed, in part, to identify radionuclides of concern, determine the respective air concentrations required to get 100 millirem (mrem) committed effective dose equivalent (CEDE), and compare actual air concentrations measured in selected LANL locations of concern to those required to get 100 mrem CEDE (NIOSH, 2019b, slide 9).

The LANL Work Group agreed with this proposed path forward, and NIOSH developed an RWP sampling plan for job-specific bioassay data completeness, to which the work group agreed. Upon receipt of what RWPs were available, NIOSH decided that an RWP sampling approach was no longer necessary and proceeded to encode the entire available set. Subsequently, NIOSH and Oak Ridge Associated Universities Team (ORAUT) issued two reports:

- ORAUT-RPRT-0102, revision 00, "Assessment of Los Alamos National Laboratory Plutonium Bioassay Programs 1996 to 2001" (ORAUT, 2021; "RPRT-0102"), on December 2, 2021
- ORAUT-RPRT-0101, revision 00, "Bounding Intakes of Exotic Radionuclides at Los Alamos National Laboratory" (ORAUT, 2022a; "RPRT-0101"), on March 1, 2022[1]

NIOSH presented these reports at the March 23, 2022, LANL Work Group meeting. An additional report, ORAUT-RPRT-0103, revision 00, "Review of Potential Exposure to Exotic Radionuclides Using Radiological Work Permit Data at Los Alamos National Laboratory" (ORAUT, 2022b; "RPRT-0103"), was released subsequently to the work group and SC&A on August 15, 2022.

At its March 23, 2022, meeting, the LANL Work Group tasked SC&A to review the first two reports and, in parallel, also tasked SC&A to review available RWPs, captured by NIOSH, as a

[1] Note: NIOSH has since issued revision 01 of RPRT-0101 (ORAUT, 2023a) to correct self-identified errors. SC&A has not officially reviewed this revision. However, based on the changes, it does not appear to materially affect the conclusions of this report.

further means to assess job-specific bioassay data completeness, particularly for source terms other than plutonium and other primary radionuclides. With the issuance of RPRT-0103, SC&A also included that report in its review.

To provide a comprehensive response to the work group's tasking, SC&A addresses the issues raised by NIOSH's reports in two ways:

1. SC&A examined the extent to which the available data and analysis in the three reports are complete and representative of the exposed population for which they are to be applied in assignment of unmonitored exposures. More specifically, did the available data sufficiently represent the worker types, time periods, source terms, and work areas in which energy employees (EEs) may have incurred the specific internal exposures? Section 2 summarizes that review.

2. SC&A reviewed the programmatic considerations for LANL implementation of bioassay programs for exotic radionuclides for the SEC time period in question. This was accomplished by reviewing the basis of NIOSH's program conclusions in the three reports, reconciling past work group concerns, and examining evidence of the adequacy of LANL bioassay program implementation following the December 31, 1995, cutoff for the preceding SEC class. That SEC designation was based on NIOSH's inability "to complete individual dose reconstructions with sufficient accuracy for internal radiological exposures to fission and activation products and various other radionuclides of concern [i.e., "exotic" radionuclides] to which these workers may have been subjected during the time period in question" (ABRWH, 2012a, p. 1). Section 3 summarizes that review.

SC&A made the following eight findings and 10 observations.

On the RPRT-0101 examination of radiological monitoring of exotic radionuclides:

- **Finding 1:** As NIOSH indicated, the evaluation of survey smear sampling and air sampling does not represent all facilities that potentially handled exotic radionuclides, nor are the data necessarily considered a random or representative sample within the three facilities evaluated. Likewise unknown are the radiological classifications of the areas the data represent.
- **Finding 2:** As NIOSH has affirmed in RPRT-0101, the dataset is not complete. Without some form of secondary source to know how many survey swipes and air sampling results were measured in the areas of interest, it is not possible to establish the level of incompleteness with the data forming the weight-of-evidence argument for 100 mrem.
- **Finding 3:** Examples of routine monitoring instructions intended to demonstrate contamination surveying and air monitoring responsibilities were dated as taking effect in the year 2000 or later (except the one for TA-48, which was effective July 1997). Additionally, examples of incidents in 1996 with fixed monitoring stations used to control contamination at location entrances were for TA-55, which is the plutonium facility and may not be representative of the facilities where exotics were handled.
- **Observation 1:** SC&A believes a clear specification of the worker job types and radionuclides covered by the 100 mrem approach is warranted for work group discussion

to clearly distinguish between the RPRT-0101 approach and any future development of co-exposure models for unmonitored workers who should have been monitored or whose records are unavailable.

- **Observation 2:** SC&A observed entries in the original dataset that were marked as duplicates but do not appear to have been deleted. However, given the small relative percentage and their observed relative magnitude, deleting these samples would likely have a minimal effect on the results.
- **Observation 3:** Air sampling data evaluated for Technical Area 53 during 1996 and 1997 showed the highest number of observed results that were above the 100 mrem limit (~33 percent and 22 percent, respectively). This was significantly higher than all other technical areas and years.

On the RPRT-0102 examination of plutonium radiological work permits:

- **Finding 4:** SC&A does not agree that an individual worker should be considered compliant with RWP bioassay requirements if ANY of the RWPs associated with that individual during the year have appropriate associated plutonium bioassays.
- **Finding 5:** SC&A does not believe the NIOSH assumption that an appropriate time window for bioassay submission of during the RWP work or by "the end of the year after the year in which the RWP expired" is an appropriate metric for assessing monitoring compliance with RWP-related work. In addition, SC&A does not believe instances where the EE submitted a plutonium bioassay during the RWP work necessarily satisfy the RWP-mandated monitoring criteria. SC&A believes the only appropriate time window for submission should be 1 year after the expiration of the RWP.
- **Finding 6:** The assumed connection between exposure potentials for workers based solely on signing the same RWP acknowledgement form is questionable. This would be particularly true for RWPs that span a significant length of time and require individual workers to perform several different tasks with variable exposure potentials.
- **Observation 4:** The lowest observed compliance with bioassay requests via the Bioassay Enrollment, Scheduling, and Tracking (BEST) system was for Johnson Controls, one of LANL's maintenance contractors, which had a low of ~45 percent compliance for 29 requests in 2001 (~72 percent compliance for all years). However, KSL Services, which appears to have been another maintenance contractor for LANL, had the highest rate of compliance observed overall (~89 percent) and was never lower than ~83 percent.
- **Observation 5:** SC&A does not agree with NIOSH's contention that the large majority of unfulfilled bioassay requests (1,613 of 1,981) were for legitimate reasons (i.e., over 97 percent of bioassay requests were either correctly fulfilled or have legitimate reasons for going unfulfilled). It is SC&A's opinion that the only legitimate reason for an unfulfilled bioassay request is that the EE was not exposed to plutonium for the entirety of the intended monitoring period.
- **Observation 6:** SC&A's objections regarding the acceptable time window for bioassay submission do not affect the RPRT-0102 estimates when considering an open window timeframe. However, SC&A notes that the later monitoring result, as used in a potential co-exposure distribution, is not guaranteed to be reflected in the intake period for which it

is intended (i.e., it would be reflected in the year the sample was taken, not the year in which the exposure was incurred).

On the RPRT-0103 examination of radiological monitoring for exotic radionuclides related to radiological work permits:

- **Observation 7:** During the period of interest from 1996 to 2005, SC&A identified 34 RWPs covering 147 workers who had tritium bioassay specified. Of these 147 RWP-worker combinations, SC&A found that approximately 73 percent were appropriately monitored throughout the assumed job period, 5 percent were partially monitored, and 22 percent were unmonitored.
- **Observation 8:** SC&A identified a single RWP covering 10 workers that specified uranium monitoring in addition to plutonium urinalysis. Five of the 10 workers did not have internal monitoring identified, 4 of 10 only had plutonium monitoring, and 1 worker had unclear records due to an undated chest count.
- **Observation 9:** SC&A identified 24 individuals with positive nasal contaminations and evaluated their internal monitoring records. The number of individuals with followup monitoring varied from 14 to 17 (58 percent to 71 percent) depending on certain assumptions about undated records and potentially invalid positive nasal swipes.

On overall programmatic considerations for internal dosimetry at LANL:

- **Finding 7:** SC&A finds that RPRT-0101 and RPRT-0103 do not demonstrate that nonroutine job-specific bioassays were adequately evaluated for potential operational exposures to exotics, and that LANL monitoring programs were being adequately implemented to ensure that unmonitored workers were unlikely to receive intakes resulting in 100 mrem CEDE.
- **Finding 8:** The results in RPRT-0102 for routine plutonium monitoring are not transferable to nonroutine, job-specific sampling for exotics, which was much more discretionary and based on individual line management or RCT judgments about job-related exposure potential.

In addition, SC&A has the following overarching summary conclusion about the application of a 100 mrem/year CEDE bounding dose for exposure by unmonitored workers to exotic radionuclides.

- **SC&A Summary Conclusion:** LANL-wide programmatic implementation of the requirement at 10 CFR 835.402(c)(1) for monitoring of potential internal exposures of 100 mrem/year CEDE, the basis for NIOSH's proposed bounding dose for unmonitored workers during 1996–2005, is found to be of questionable adequacy, with major deficiencies not corrected until at least the end of 2000. This inadequacy undercuts the use of that threshold dose as bounding for unmonitored worker exposure to mixed activation products, mixed fission products, and other exotic radionuclides.

1 Introduction and Background

1.1 Introduction

At its meeting of March 23, 2022, the Los Alamos National Laboratory (LANL) Work Group tasked SC&A, Inc. to:

1. Review the following recently issued National Institute for Occupational Safety and Health (NIOSH) reports:
    - ORAUT-RPRT-0101, revision 00, "Bounding Intakes of Exotic Radionuclides at Los Alamos National Laboratory" (ORAUT, 2022a; "RPRT-0101")
    - ORAUT-RPRT-0102, revision 00, "Assessment of Los Alamos National Laboratory Plutonium Bioassay Programs 1996 to 2001" (ORAUT, 2021; "RPRT-0102")
2. In parallel, review available radiological work permits (RWPs), captured by NIOSH, as a further means to assess job-specific bioassay data completeness, particularly for source terms other than plutonium and other primary radionuclides. For this review, NIOSH provided the RWP dataset obtained from LANL.

On August 15, 2022, NIOSH also issued ORAUT-RPRT-0103, revision 00, "Review of Potential Exposure to Exotic Radionuclides Using Radiological Work Permit Data at Los Alamos National Laboratory" (ORAUT, 2022b; "RPRT-0103"), which is also addressed in this review.

To provide a comprehensive response to the work group's tasking, SC&A addresses the issues raised by NIOSH's reports in two ways:

1. SC&A examined the extent to which the available data and analysis in the three reports are complete and representative of the exposed population for which they are to be applied in assignment of unmonitored exposures. More specifically, did the available data sufficiently represent the worker types, time periods, source terms, and work areas in which energy employees (EEs) may have incurred the specific internal exposures? Section 2 summarizes that review.
2. SC&A reviewed the programmatic considerations for LANL implementation of bioassay programs for exotic radionuclides for the Special Exposure Cohort (SEC) time period in question. This was accomplished by reviewing the basis of NIOSH's program conclusions in the three reports, reconciling past work group concerns, and examining evidence of the adequacy of LANL bioassay program implementation following the December 31, 1995, cutoff for the current SEC class. That SEC designation was based on NIOSH's inability "to complete individual dose reconstructions with sufficient accuracy for internal radiological exposures to fission and activation products and various other radionuclides of concern [i.e., "exotic" radionuclides] to which these workers may have been subjected during the time period in question" (ABRWH, 2012a, p. 1). Section 3 summarizes that review.

1.2 Background

Petition SEC-00109 was received on April 3, 2008, and qualified on May 29, 2008, with an evaluation report (ER) issued on January 22, 2009 (revised on August 15, 2012), and an Addendum issued on April 24, 2017. The class evaluated is all "Service Support Workers . . . from January 1, 1976 through December 31, 2005" (NIOSH, 2012b, p. 1). The Advisory Board on Radiation and Worker Health (ABRWH, Board) recommended and an SEC class was designated in 2012 for the earlier period of 1976–1995:

> All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico, from January 1, 1976, through December 31, 1995, for a number of work days aggregating at least 250 work days, occurring either solely under this employment, or in combination with work days within the parameters established for one or more other classes of employees in the Special Exposure Cohort. [ABRWH, 2012a, p. 1]

The basis for this class being added included the "inability to bound unmonitored intakes of exotic alpha emitters, fission products, activation products, tritium (STCs), Sr/Y-90, Th-230 and Th-232" (NIOSH, 2017b, slide 4). The end date (December 31, 1995) for this SEC class was based on the "presumption that LANL would have been in full compliance with 10 CFR 835, *Occupational Radiation Protection*, by then" (NIOSH, 2017b, slide 4).

In the Addendum to the SEC-00109 ER, NIOSH finds dose reconstruction (DR) with sufficient accuracy feasible for service support workers in 1996–2005 given the enactment of the requirements in Title 10 of the Code of Federal Regulations (10 CFR) Part 835 at LANL on January 1, 1996. As noted by NIOSH, "10 CFR 835 requires internal dosimetry programs (including routine bioassay programs) for Radiological workers who, under typical conditions, are likely to receive a committed effective dose equivalent (CEDE) of 0.1 rem (0.001 sievert) or more from all occupational radionuclide intakes in a year" (NIOSH, 2017b, slide 5). In the absence of individual internal dosimetry data, NIOSH presumes "intakes would be unlikely to have resulted in greater than 0.1 rem CEDE," and, therefore, the "infeasibility to reconstruct dose would not exist" (NIOSH, 2017b, slide 5). To summarize, NIOSH presumes that compliance with the 10 CFR Part 835 rule by that date resolves the DR limitations on which the preceding SEC class was based.

SC&A's review of and response to the Addendum made several key points (SC&A, 2017b, slide 6):

- **Compliance** is not equivalent to **Implementation**.
- Reviewing actual dosimetry program implementation is important for DR because non-adherence or non-participation can lead to monitoring gaps.
- Reviewing oversight or compliance findings is necessary but not sufficient for establishing soundness of dosimetry programs.

- Improvements in internal dosimetry at DOE sites were evolutionary during 1990s – no uniform timing for full and successful conformance with all requirements.[2]

From these standpoints, SC&A reviewed the U.S. Department of Energy (DOE) Noncompliance Tracking System (NTS), Occurrence Reporting and Processing System (ORPS), and oversight issues for LANL for the 1996–2005 period. From this review, one 1999 noncompliance stands out, NC ID 484, for which broad issues with the internal dosimetry monitoring program were cited, including 10 CFR 835.402(c)(1) violations involving incomplete bioassay checklists, missing RWP job-specific bioassays, and shortcomings in construction trade worker bioassay enrollment. SC&A's review established that the original bioassay inadequacies and lack of monitoring for mixed activation products (MAPs) and mixed fission products (MFPs) identified in the prior SEC period had not been demonstrably resolved by 1996 despite the implementation of and presumed compliance with 10 CFR Part 835 monitoring requirements at LANL.

NIOSH's November 29, 2018, presentation to the LANL Work Group, "NIOSH's Response to SC&A's Review of the SEC-00109 LANL Addendum" (NIOSH, 2018b), included the following considerations and path forward (slide 5):

- Based on the SC&A review and the Advisory Board's reaction, NIOSH decided to re-evaluate [its] approach for the 10 CFR 835 time period
- NIOSH concurs with SC&A's assessment that: compliance with the 10 CFR 835 milestone may not be sufficient for demonstrating actual implementation of the requirements; and reliance on oversight findings may not be sufficient for validating LANL had fully implemented 10 CFR 835
- NIOSH determined that to increase the "weight of the evidence," additional data analysis would be required

In its expanded "weight of the evidence" review, NIOSH contended that the use of exotic radionuclides at LANL was "rare" into the 1990s and that LANL internal dosimetry programs were "established on an as-needed basis and monitoring is only required for radiological workers likely to receive 100 mrem annually from internal exposures" (NIOSH, 2018b, slide 8). NIOSH also reviewed LANL's internal dose monitoring programs for the period in question and concluded that "The field monitoring and contamination control programs at LANL were well-established and formalized by January 1, 1996 to ensure areas where workers were likely to exceed 100 mrem CEDE were well identified and controlled." Other conclusions were that "Based on review of existing bioassay results, workers monitored for the primary radionuclides were unlikely to have received intakes exceeding 100 mrem CEDE," and that "Based on the routine monitoring and contamination control established NIOSH has no reason to believe

[2] There was no uniform timing for full and successful conformance with all requirements (including 10 CFR Part 835) until Department of Energy Laboratory Accreditation Program (DOELAP) accreditation became a reality in 2002.

intakes of exotic radionuclides for unmonitored workers would be different" (NIOSH, 2018b, slide 19).

In its review of NIOSH's response paper, SC&A disagreed that there was "any new evidence that is sufficiently persuasive to contribute to the weight of evidence for this SEC-related evaluation, other than for the LANL primary radionuclides" (SC&A, 2018a, p. 20). As SC&A concluded regarding NIOSH's position (SC&A, 2018b, slide 15), there is a—

- Lack of substantiation that 100 mrem/year CEDE bounds unmonitored intakes of exotics after 1995; available evidence supports only primary radionuclides
- Lack of follow-up to establish whether 1999 LANL findings regarding bioassay program deficiencies demonstrate data inadequacy and incompleteness significant enough to impair dose reconstruction

And, in general (SC&A, 2018b, slide 15):

- DOE enforcement moratorium in 1998 underscores [the] "commonality" of serious bioassay program deficiencies across DOE sites despite implementation of 10 CFR Part 835 almost 3 years before; uniform site implementation of 100 mrem/year CEDE as basis for compliant bioassay monitoring should not be assumed [in this case, for LANL]

NIOSH issued a more detailed assessment in 2019 (NIOSH, 2019a) regarding the 1999 DOE compliance findings in NTS Report NC ID 484. In that paper, NIOSH noted that "concerns persist over how the deficiencies identified in NC ID 484 could potentially affect NIOSH's ability to bound unmonitored worker intakes," despite NIOSH's claim that "it does not rely solely on 10 C.F.R. 835 compliance for the conclusion that unmonitored workers were unlikely to have received intakes resulting in greater than 100 mrem CEDE" and that, in any case, NIOSH has a "substantial amount of internal dosimetry data for LANL workers" (NIOSH 2019a, p. 3). NIOSH found that these data show that "intakes for monitored workers during the 1996-2005 time period were generally less than 100 mrem CEDE and NIOSH believes that intakes for unmonitored workers would likely have been even lower" (NIOSH, 2019a, p. 3). NIOSH notes that it has "not identified any dose reconstruction infeasibilities for the primary radionuclides at LANL" and that "LANL has had effective routine bioassay programs in place for these radionuclides throughout the period under evaluation and sufficient bioassay data are available to NIOSH" (NIOSH, 2019a, p. 28). NIOSH further concluded that the concerns and issues identified in NC ID 484 were for the routine bioassay monitoring program and that the routine bioassay programs were directed at the primary radionuclides, not exotics.

In its review of NIOSH's review of NC ID 484, SC&A agreed that the issues surrounding NC ID 484 pertain mostly to the primary radionuclides and relate to the statistical validity of the database underpinning the current coworker model for them. However, SC&A disagreed with NIOSH's assessment that the amount of routine bioassay data available obviates the need to confirm its completeness in the face of NC ID 484 findings of potential data gaps for bioassay enrollments and RWP job-specific bioassay participation. In terms of a recommended path forward, SC&A noted that it stood by its original recommendation to the work group that

"NIOSH follow up with LANL to ascertain whether the bioassay incompleteness identified in this limited sampling in 1999 reflects a broader incompleteness in LANL's bioassay database for 1996–2000" (SC&A, 2019, p. 10). As SC&A noted, such an indication would bring into question the statistical validity of the current co-exposure model for assigning unmonitored doses for LANL workers.

NIOSH's presentation at the July 25, 2019, work group meeting acknowledged that SC&A "disagrees with NIOSH's assessment that the amount of routine bioassay data available obviates the need to confirm its completeness in the face of NC ID 484 findings [of] potential data gaps for bioassay enrollment and RWP job-specific bioassay participation," and recommended that "NIOSH follow up with LANL to ascertain whether the bioassay incompleteness identified in the limited sampling in 1999 reflects a broader incompleteness in LANL's bioassay database for 1996-2000" (NIOSH, 2019b, slide 3). However, a joint NIOSH-SC&A interview with knowledgeable LANL staff determined that "There was nothing done at the time to determine the magnitude of individuals not leaving the required bioassay," and that for other issues (such as inadequacies in workers completing RWP-related checklists), corrective actions were only taken to remedy monitoring program shortcomings going forward (NIOSH, 2019b, slide 4). NIOSH acknowledged that a "similar situation occurred during the SRS [Savannah River Site] evaluation" regarding questions about the completeness of RWP-directed, job-specific bioassays and that "In order to resolve that issue, NIOSH agreed to develop a sampling plan and sample RWP's to determine compliance with bioassay requirements" (NIOSH, 2019b, slide 5). Similarly, following NIOSH's assessment that "it would be feasible to conduct the [RWP] sampling at LANL during the 1996-2001 period," the plan was to "move forward with the sampling plan effort consistent with how it was conducted at SRS" (NIOSH, 2019b, slides 6, 7).

For the other principal issue of "Mixed Fission and Activation Products/Exotics," the NIOSH proposal at the July 25, 2019, work group meeting was the following (NIOSH, 2019b, slide 9):

- Identify radionuclides of concern
- Determine respective air concentrations required to get 100 mrem CEDE
- Identify areas where the potential existed for exposure to MFAP/Exotics
- Capture air sample data from these areas
- From those areas identify areas of greatest concern
- Compare actual air concentrations to those required to get 100 mrem CEDE

The LANL Work Group agreed with NIOSH's proposed path forward on the two key issues and looked to a possible November 2019 work group meeting to discuss NIOSH's sampling plan and data capture. However, holdups in receiving records from LANL, compounded by the coronavirus pandemic beginning in early 2020, delayed this schedule. Notwithstanding these delays, by early 2020, sufficient RWPs had been collected by NIOSH (3,200–3,300 RWPs) to enable coding of the entire set, negating the need for a sampling plan and allowing an analysis of the entire set of available RWPs. Subsequently, NIOSH released RPRT-0102 on December 27, 2021, and RPRT-0101 on March 16, 2022.[3] These reports were subsequently presented at the

[3] Dates are the "DOE Review Release" dates; NIOSH issue dates for RPRT-0102 and RPRT-0101 were December 2, 2021, and March 1, 2022, respectively.

March 23, 2022, LANL Work Group meeting. NIOSH subsequently released RPRT-0103 to the work group and SC&A on September 9, 2022, with an effective date given as August 15, 2022.[4]

[4] Two reports subsequently have been issued regarding LANL since the work group last met on these issues: (1) A memo report, "Weight of Evidence Supports NIOSH's Ability to Bound LANL TA-53 Doses for 1996–2005," August 15, 2023 (NIOSH, 2023), and (2) ORAUT-RPRT-0107, revision 00, "Dose Estimation from Intakes of Exotic Radionuclides at the Los Alamos Neutron Science Center, 1996 to 2005," September 15, 2023 (ORAUT, 2023b). SC&A has not yet been tasked by the LANL Work Group to review these more recent assessments.

2 SC&A Review of Data Adequacy Supporting Co-exposure Model Development for Plutonium and 100 mrem CEDE Bounding Dose for Exotics

The following subsections of this report describe SC&A's review approach for the three main reports by NIOSH that were designated with effective dates during 2021 and 2022:

1. Section 2.1: RPRT-0101, "Bounding Intakes of Exotic Radionuclides at Los Alamos National Laboratory" (ORAUT, 2022a)
2. Section 2.2: RPRT-0102, "Assessment of Los Alamos National Laboratory Plutonium Bioassay Programs 1996 to 2001" (ORAUT, 2021)
3. Section 2.3: RPRT-0103, "Review of Potential Exposure to Exotic Radionuclides Using Radiological Work Permit Data at Los Alamos National Laboratory" (ORAUT, 2022b)

Section 5 summarizes SC&A's conclusions about all three reports.

SC&A's general review approach for these three companion reports is to examine the extent to which the available data that will underpin the proposed bounding approach (in the case of RPRT-0101) or the more traditional potential co-exposure models (in the case of RPRT-0102 and RPRT-0103) are complete and representative of the exposed population they are intended to represent. More specifically, that the available data sufficiently represent the worker types, time periods, source terms, and work areas from which EEs may have incurred the specific internal exposures.

It is worth noting that, to date, SC&A has not identified any issues with the adequacy of the data, which is defined in DCAS-IG-006, revision 00, "Criteria for the Evaluation and Use of Co-exposure Datasets," as the data "are capable of quantitatively measuring the exposure of interest" (NIOSH, 2020, p. 5). For RPRT-0101, we discuss stratification in the context of the locations and time periods of the available area monitoring data. As it applies to RPRT-0102 and RPRT-0103, stratification would typically be evaluated at a potential future co-exposure modeling stage.

2.1 Examination of radiological monitoring of exotic radionuclides (RPRT-0101)

Section 2.1 reviews RPRT-0101 in the context of the entirety of the internal dose reconstruction issues at LANL during the period 1996–2005. This section is split into five main subsections:

- Section 2.1.1: purpose and scope of the report
- Section 2.1.2: areas covered in the evaluation
- Section 2.1.3: characterization of the available contamination survey and air sampling data
- Section 2.14: evaluation of the radiological control program
- Section 2.1.5: conclusions about assignment of internal doses to unmonitored workers from exotic radionuclides

2.1.1 Purpose and scope of RPRT-0101

Section 1.2 of RPRT-0101 (ORAUT, 2022a, p. 8) states that the purpose of this report is to analyze available routine air monitoring (general area air monitoring) and routine surface contamination monitoring data for potential radionuclides of interest defined as "exotic radionuclides" (hereafter referred to as "exotics"). In addition, the report discusses the radiological control program at LANL in general and with a focus on portal monitors and other hand and foot monitors used at the site to control the spread of any potential contamination.

However, the RPRT-0101 definition of exotics is unclear: specifically, whether NIOSH considers all isotopes other than plutonium, uranium, and tritium to be exotic. Section 1.0 of RPRT-0101 notes that the SEC-00109 ER (NIOSH, 2012b) defined "exotic radionuclides" as "everything other than $^{234/235/238}$U, $^{238/239}$Pu, ^{3}H, ^{241}Am, and ^{137}Cs" (ORAUT, 2022a, p. 6). In contrast, section 1.1 (p. 7) appears to define the focus of RPRT-0101 as "nonplutonium radionuclides. These radionuclides include exotic radionuclides and heavy elements such as ^{227}Ac, ^{237}Np, ^{241}Am, ^{244}Cm, and thorium." Later in the same section, RPRT-0101 (p. 7) states:

> During LANL Work Group deliberations, routine work monitoring has been described as monitoring for plutonium, uranium, and tritium. Such routine work is defined as work not done under a radiation work permit (RWP) and that involved workers such as guards and custodians.

Previous LANL SEC reports do not clarify NIOSH's characterization of exotics. The SEC-00109 ER makes statements concerning the prior SEC evaluations (specifically SEC-0051) that appear to define exotics as "mixed fission and mixed activation products" (NIOSH, 2012b, p. 20). Specifically, Petition-0051 lists "Th-232, Cm-244, Ac-227, Cf-252, Np-237, Am-241, and U-233" (NIOSH, 2007, p. 106). SC&A confirmed that the SEC-00109 ER defined exotics "to include everything other than U-234/235/238, Pu-238/239, tritium, Am-241, and Cs-137" (NIOSH, 2012b, p. 41); i.e., radionuclides for which there are limited or no internal dosimetry data. The SEC-00109 Addendum ER stated that "Less-common sources included Sr-90/Y-90, Th-230, Th-232, Np-237, Ac-227, Pa-231, Cm-244, fission products, activation products, special tritium compounds (STCs), and others" (NIOSH, 2017a, p. 9).

In addition, RPRT-0101 states the following about the types of workers to whom this report and its conclusions are meant to apply (ORAUT, 2022a, p. 7):

> Emphasis is placed on workers doing routine work, such as guards and custodians, and actions taken during contamination incidents.

Ultimately, RPRT-0101 concluded:

> The ORAU Team concludes the weight of the evidence clearly indicates that worker doses to unmonitored exotic radionuclides would not likely have exceeded 100 mrem. Doses for workers monitored by bioassay can be bounded using bioassay results. [ORAUT, 2022a, p. 27]

Based on this conclusion, it would appear that 100 millirem (mrem) will be applied to unmonitored workers whether (a) evidence suggests they should have been monitored and were not or (b) their records are otherwise unavailable. Specifically, section 4.0 (p. 27) states:

> Doses for workers monitored by bioassay can be bounded using bioassay results. Doses for unmonitored workers can be bounded at 100 mrem because no evidence was found that would contradict these conclusions. Therefore, the assumption, based on data and facts provided in the report, is that no unmonitored workers received a dose above 100 mrem/yr during normal operations.

From the RPRT-0101 statements summarized in this section, it could be inferred that the 100 mrem CEDE approach proposed applies to workers with no bioassay records for non-plutonium/uranium/tritium isotopes and, in general, workers who are expected to have lower exposure potential than more typical operational worker job categories such as glovebox operators and other hands-on operations with radioactive material. However, the exact scope of this proposed DR methodology and the classes of workers should be explicitly specified and discussed by the work group.

Observation 1: SC&A believes a clear specification of the worker job types and radionuclides covered by the 100 mrem approach is warranted for work group discussion to clearly distinguish between the RPRT-0101 approach and any future development of co-exposure models for unmonitored workers who should have been monitored or whose records are unavailable.

2.1.2 Areas analyzed in RPRT-0101

Section 1.1 of RPRT-0101 (ORAUT, 2022a, p. 7) states:

> three TAs [technical areas] where exotic radionuclides are known to have been handled were selected for review: the South Mesa Site (TA-3) containing Chemistry and Metallurgy Research (CMR); the Meson Physics Facility (TA-53) containing the LANSCE [Los Alamos Neutron Science Center]; and the Radiochemistry Site (TA-48).

NIOSH acknowledges that these three areas are not the only areas at LANL in which exotics were handled and explains that "This exercise was not intended to be all inclusive of all areas at LANL that handled exotic radionuclides" (ORAUT, 2022a, p. 18). In addition, RPRT-0101 states that "evaluated data do not represent a random sample of all survey data" (ORAUT, 2022a, p. 21).

Furthermore, section 2.0 of RPRT-0101 outlines the four general classifications of potential contamination areas that might be contained within the three TAs that were analyzed in the report. These radiological characterizations are essentially a stepwise function as far as exposure potential and are summarized by SC&A as follows:

- Contamination Area: accessible areas where removable surface contamination is likely to be between 1 and 100 times the values specified in 10 CFR Part 835, Appendix D, nominally 20 disintegrations per minute per 100 square centimeters (dpm/100 cm^2) for alpha and 1,000 dpm/100 cm^2 for removable beta

- Airborne Radioactivity Area: accessible areas where air concentrations exceed the derived air concentration (DAC) a worker might be exposed to or exceed 12 DAC-hours cumulatively during a week with no respiratory protection
- Radiological Buffer Area: area that provides the boundary for workers who were not considered radiological workers
- Controlled Area: all other areas in which individuals must be protected from exposure to radiation

Regarding how these potential contamination areas apply to the analysis of the three site TA locations in RPRT-0101, the report states:

> While the ORAU Team does not have specific documentation specifying the controlled contamination designations of areas in these three areas, all of these areas were controlled under routine monitoring. [ORAUT, 2022a, p. 21]

SC&A acknowledges that the intent of RPRT-0101 was to provide a scoping illustrative analysis rather than a strictly quantitative one. The report emphasizes several times that the evaluation represents a weight-of-evidence argument, including in the concluding section:

> While data used in the report are not the total set of data collected by LANL, the weight of evidence supports that premise. . . .
>
> The ORAU Team concludes the weight of the evidence clearly indicates that worker doses to unmonitored exotic radionuclides would not likely have exceeded 100 mrem. [ORAUT, 2022a, p. 27]

SC&A feels that it is important to reemphasize that this weight-of-evidence argument has the following limitations:

1. It does not represent all potential facilities and locations that handled exotic radionuclides.

2. It is unknown whether the data (both swipe survey and air monitoring) represent locations within the TAs that can be classified as a contamination area, airborne contamination area, radiological buffer area, or controlled area.

3. The data for the three TAs are not considered by NIOSH a random sample, nor is it known if the data are a representative sample within the TAs.

Finding 1: As NIOSH indicated, the evaluation of survey smear sampling and air sampling does not represent all facilities that potentially handled exotic radionuclides, nor are the data necessarily considered a random or representative sample within the three facilities evaluated. Likewise unknown are the radiological classifications of the areas the data represent.

On completeness in general, SC&A inquired via email of NIOSH whether there were any secondary sources (such as periodic health physics reports) that may be used to gauge what

percentage of the survey swipe samples and air sampling results may have been taken over time in the three facilities included in this analysis. This would provide some idea of the amount of data that has actually been captured compared to the amount of data that could potentially exist. However, NIOSH indicated no such comparison has been made to date, and it does not appear as though such tabulations have been captured (it is also not known whether LANL ever made such tabulations). NIOSH acknowledged this in RPRT-0101, section 1.1 (p. 7): "NIOSH makes no claim that these data are complete."

Finding 2: As NIOSH has affirmed in RPRT-0101, the dataset is not complete. Without some form of secondary source to know how many survey swipes and air sampling results were measured in the areas of interest, it is not possible to establish the level of incompleteness with the data forming the weight-of-evidence argument for 100 mrem.

Despite these limitations, SC&A found it prudent to perform an independent evaluation of the available data to help characterize the temporal and location-specific distribution of the captured and analyzed dataset. This analysis is described in section 2.1.3 of this report.

2.1.3 Characterization of data used in RPRT-0101

This section describes the data provided by NIOSH on August 16, 2022, that underpin the analysis in RPRT-0101. SC&A describes what data appear to be excluded from the analysis (refer to section 2.1.3.1), provides a temporal characterization of the data by year and by TA (refer to section 2.1.3.2), and provides a building-specific characterization within each TA (refer to section 2.1.3.3). The purpose of this section is to provide the LANL Work Group with further information and to illustrate the acknowledged limitations of the qualitative analysis presented in RPRT-0101 to help inform discussions on the weight-of-evidence conclusion that 100 mrem is appropriate for reconstructing doses to unmonitored workers. In addition, characterizing the limited data temporally and then by building within the three TAs is intended to determine whether there might be situations in which the conclusion that 100 mrem is bounding may need closer examination; for example, if a given year or building consistently showed elevated surface contamination and/or air monitoring results that differed significantly from the conglomeration of the data by TA across the entire period of interest.

2.1.3.1 Data excluded from RPRT-0101 analysis

The dataset provided by NIOSH contains 3,515 distinct entries, with each line item representing either a contamination survey or an air sample survey report entry.[5] Table 1 shows a general summary of the number of report entries and associated number of samples, along with the number and percentage of each that were used and not used in the RPRT-0101 analysis.

[5] Note: a single entry may represent anywhere from 1 to 216 individual contamination swipe survey results and 1 to 74 air sampling results.

Table 1. Summary of data used in RPRT-0101

Type of area monitoring	Total reports	Total deleted reports	Total reports used in RPRT-0101 (%)	Total samples	Total samples deleted in RPRT-0101 (%)	Total samples used in RPRT-0101 (%)
Contamination survey	1,336	343 (25.7%)	993 (74.3%)	51,091	8,631 (16.9%)	42,460 (83.1%)
Air monitoring	2,179	231 (10.6%)	1,948 (89.4%)	72,804	3,978 (5.5%)	68,826 (94.5%)
Total area monitoring reports	3,515	574 (16.3%)	3,515 (83.7%)	123,895	12,609 (10.2%)	123,895 (89.8%)

As seen in table 1, the total number of report entries (or database line items) (83.7 percent of the total) and the total number of actual sample results used in the formulation of RPRT-0101 (89.8 percent) were fairly similar. Typical reasons NIOSH gave for deleting contamination survey and air sampling results included the following:

- Data represented nonroutine conditions rather than general area conditions (e.g., RWPs, surveys inside a hood, survey of equipment/tools with known contamination, target swipes, etc.).
- Results could not be interpreted for the purposes of the analysis (e.g., the results were in counts per minute (cpm) rather than dpm, alpha/beta/gamma were all combined, etc.).
- Results were taken as a large area swipe.
- Reported values were direct readings only (i.e., included the fixed portion of the contamination).
- Results were identified as directly related to nonexotic radionuclides.
- Reports indicated the results were part of a recount or quality assurance test rather than an independent set of data.
- Samples were duplicated in other references already captured and entered.

On this last bullet, SC&A also observed report entries and associated samples that appeared to have been identified as duplicates in the dataset but were not deleted and were designated for use in RPRT-0101. While it is unclear why these entries were apparently still included, they make up a very small percentage of the overall dataset:

- 31 reports (~3.1 percent of total) for contamination surveys representing 2,043 individual measurements (~4.8 percent of total)
- 31 individual measurements (~1.6 percent) for air monitoring representing 1,758 individual measurements (~2.6 percent of total)

Observation 2. SC&A observed entries in the original dataset that were marked as duplicates but do not appear to have been deleted. However, given the small relative percentage and their observed relative magnitude, deleting these samples would likely have a minimal effect on the results.

2.1.3.2 Examination of data by technical area and year

This section provides summary characteristics by TA and year to ascertain whether there are certain years and general TAs in which elevated contamination surveys and air monitoring results are evident. In addition, breaking out the data by year can help illustrate any temporal limitations in the dataset as far as quantity and scope of the data. Each TA is presented in its own subsection. The observed contamination survey results and air samples are compared against a set of limits that are intended to give perspective on the actual radiological levels reflected in the records. The administrative limits refer to the actual limits imposed administratively by LANL and conform to 10 CFR Part 835; the 100 mrem limits refer to the level at which 100 mrem would be incurred using typical health physics parameters for breathing rate, resuspension factor, and annual exposure time. These limits are as follows:

- Administrative alpha surface contamination limit: 20 dpm/100 cm^2
- Administrative beta surface contamination limit: 1,000 dpm/100 cm^2
- 100 mrem alpha surface contamination limit: 400 dpm/100 cm^2
- 100 mrem beta surface contamination limit: 3,200,000 dpm/100 cm^2
- 100 mrem alpha air concentration limit: 0.04 dpm per cubic meter (dpm/m^3)
- 100 mrem beta air concentration limit: 320 dpm/m^3

No comparisons were made to an administrative limit for air sampling, as these would be expressed in the units of DAC, which is related to the level of radioactivity in air that would result in 5 rem annually (as opposed to 100 mrem annually). Thus, the equivalent administrative limits for airborne radioactivity are not relevant to the RPRT-0101 discussion.

Temporal characteristics of Technical Area 3

Figure 1 displays the total number of contamination surveys and air monitoring results by year for TA-3. Table 2 presents the number of contamination surveys that exceeded the administrative and 100 mrem limits by year. As seen in the figure and table, the number of contamination surveys increased significantly in 1999, which also coincided with a significant increase in the number of results that were above the administrative limit for alpha and beta (~17 percent and 1 percent, respectively). This increase was also seen in the number of results above the 100 mrem limit; however, the number of results above the limit was still below 1 percent of the total number of alpha samples. No beta contamination surveys had results above the 100 mrem limit. However, it should be noted that since this is not considered a random nor representative sample, these results could be an artifact of the characteristics of those records that were available and captured by NIOSH.

Figure 1. Total number of surface contamination surveys and air concentration monitoring results by year for TA-3

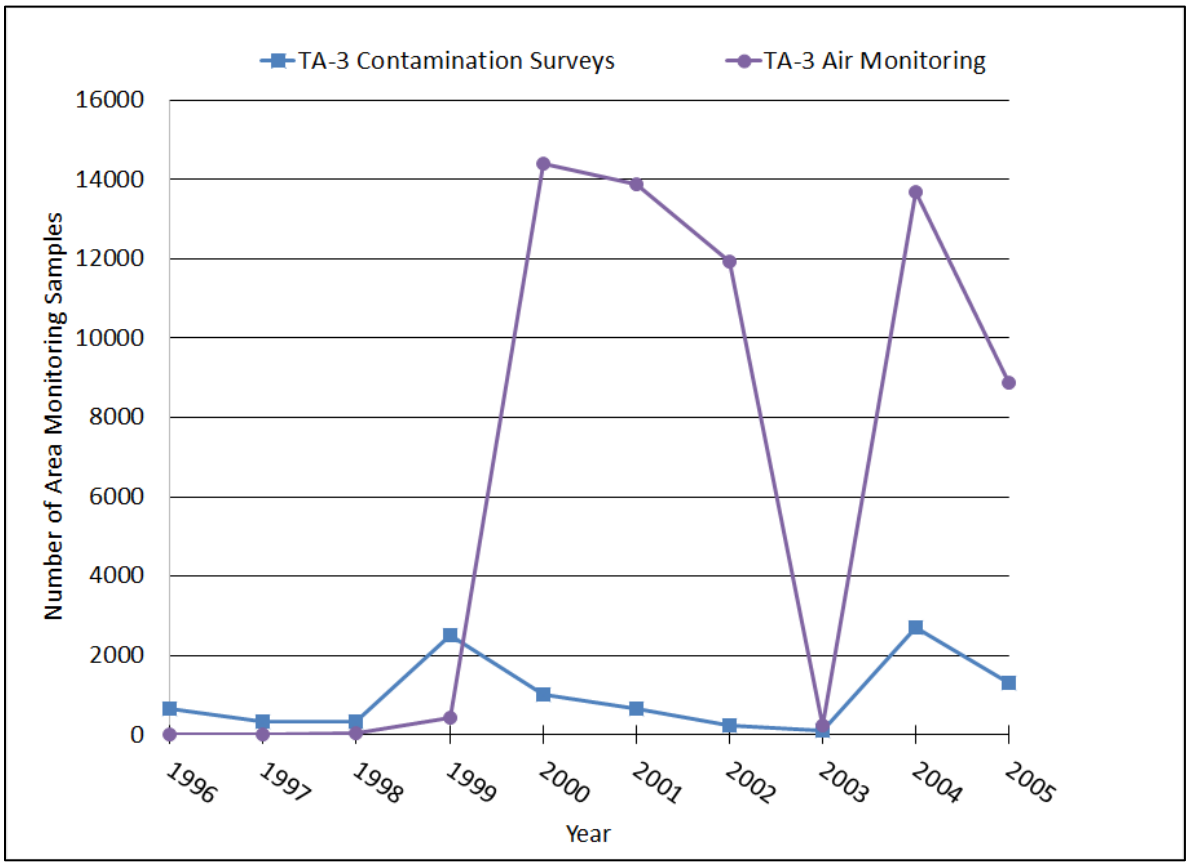


Table 2. Number of TA-3 surface contamination surveys exceeding administrative and 100 mrem limits by year

Year	Number of contamination surveys	Number exceeding administrative alpha limit (% of total)	Number exceeding 100 mrem alpha limit (% of total)	Number exceeding administrative beta limit (% of total)	Number exceeding 100 mrem beta limit (% of total)
1996	645 *	5 (0.8%)	1 (0.2%)	1 (0.2%)	0 (0.0%)
1997	331	4 (1.2%)	1 (0.3%)	0 (0.0%)	0 (0.0%)
1998	343	31 (9.0%)	1 (0.3%)	0 (0.0%)	0 (0.0%)
1999	2,504	416 (16.6%)	16 (0.6%)	108 (4.3%)	0 (0.0%)
2000	1,021	49 (4.8%)	6 (0.6%)	3 (0.3%)	0 (0.0%)
2001	649	5 (0.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
2002	220	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
2003	119	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
2004	2,720	142 (5.2%)	3 (0.1%)	0 (0.0%)	0 (0.0%)
2005	1321	10 (0.8%)	1 (0.1%)	0 (0.0%)	0 (0.0%)

* Number of alpha and beta contamination surveys differ slightly in this year because 15 smear surveys were identified that only contained beta results.

Table 3 presents the number of air sampling results that exceed the 100 mrem limit. As shown in table 3 and figure 1, there was no corresponding increase in air sampling in 1999 as observed in

the contamination surveys. Instead, there was a significant increase in available records in the subsequent 3 years (2000–2002). One could postulate that the increase in air sampling was a result of observed contamination surveys in 1999, with the caveat that this is not a random nor representative sample. All observed air sampling results were much less than 1 percent of the 100 mrem limit for alpha, and no observed beta air samples exceeded the 100 mrem limit.

Table 3. Number of TA-3 air concentration samples exceeding the 100 mrem limit

Year	Air samples	Exceed 100 mrem alpha limit # (%)	Exceed 100 mrem beta limit # (%)
1996	0	NA	NA
1997	6	0 (0.0%)	0 (0.0%)
1998	0	NA	NA
1999	434	0 (0.0%)	0 (0.0%)
2000	14,399	60 (0.4%)	0 (0.0%)
2001	13,885	50 (0.4%)	0 (0.0%)
2002	11,919	73 (0.6%)	0 (0.0%)
2003	250	0 (0.0%)	0 (0.0%)
2004	13,682	9 (0.1%)	0 (0.0%)
2005	8,880	5 (0.1%)	0 (0.0%)

Temporal characteristics of Technical Area 48

Figure 2 displays the total number of contamination surveys and air monitoring results by year for TA-48. Table 4 presents the number of contamination surveys that exceeded the administrative and 100 mrem limits by year. As seen in figure 2 and table 4, the highest number of surveys evaluated was in 1997 (4,819 results), and this year also showed the highest number of results that were above the administrative limit (~1 percent) for alpha. Less than 0.1 percent of the results for both alpha and beta in this year were above the hypothetical 100 mrem limit. There were no observed contamination surveys that had results above the 100 mrem limit. Although two years evaluated had contamination surveys in the 1,000s of results, most other years only had a few hundred results for evaluation.

Figure 2. Total number of surface contamination surveys and air concentration monitoring results by year for TA-48

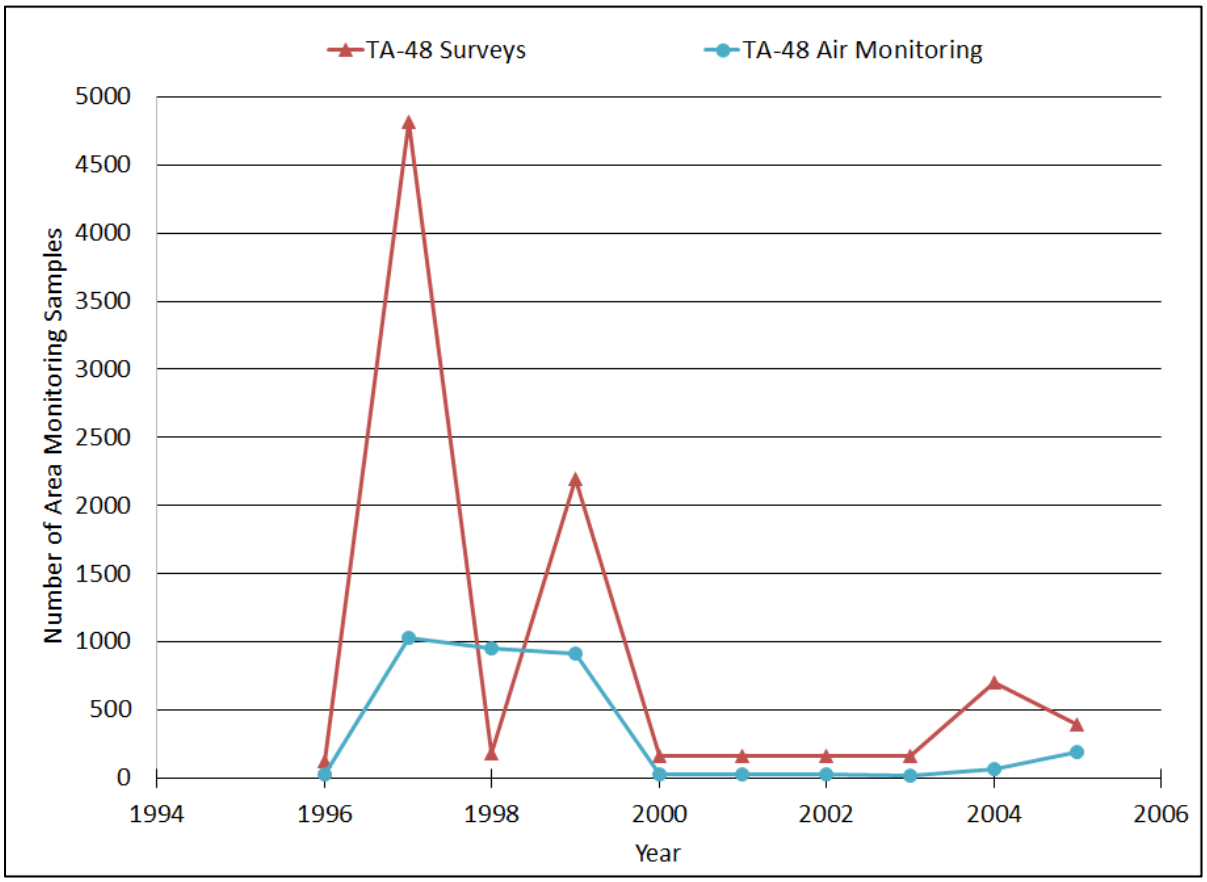


Table 4. Number of TA-48 surface contamination surveys exceeding administrative and 100 mrem limits by year

Year	Number of contamination surveys	Number exceeding administrative alpha limit (% of total)	Number exceeding 100 mrem alpha limit (% of total)	Number exceeding administrative beta limit (% of total)	Number exceeding 100 mrem beta limit (% of total)
1996	125	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
1997	4,819	47 (1.0%)	4 (0.1%)	2 (0.0%)	0 (0.0%)
1998	180	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
1999	2,199	7 (0.3%)	0 (0.0%)	49 (2.2%)	0 (0.0%)
2000	0	NA	NA	NA	NA
2001	0	NA	NA	NA	NA
2002	0	NA	NA	NA	NA
2003	0	NA	NA	NA	NA
2004	700	2 (0.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
2005	396 *	1 (0.3%)	0 (0.0%)	3 (0.9%)	0 (0.0%)

* This represents the total number of alpha contamination surveys. There were 50 fewer beta survey measurements during the year (346 total).

Table 5 presents the number of air sampling results that exceed the 100 mrem limit. As shown in table 5 and figure 2, the most air samples available for evaluation were during the years 1997–1999, when roughly 1,000 samples were available per year. This period also corresponded to the only observed air samples that exceeded the 100 mrem limit for alpha. All other years had zero observed instances of air samples exceeding the 100 mrem limit for both alpha and beta.

Table 5. Number of TA-48 air concentration samples exceeding the 100 mrem limit

Year	# Air samples	Exceed 100 mrem alpha limit # (%)	Exceed 100 mrem beta limit # (%)
1996	28	0 (0.0%)	0 (0.0%)
1997	1,031	13 (1.3%)	0 (0.0%)
1998	950	11 (1.2%)	0 (0.0%)
1999	919	5 (0.5%)	0 (0.0%)
2000	0	NA	NA
2001	0	NA	NA
2002	0	NA	NA
2003	18	0 (0.0%)	0 (0.0%)
2004	72	0 (0.0%)	0 (0.0%)
2005	196	0 (0.0%)	0 (0.0%)

Temporal characteristics of Technical Area 53

Figure 3 displays the total number of contamination surveys and air monitoring results by year for TA-53. Table 6 presents the number of contamination surveys that exceeded the administrative and 100 mrem limits by year. As seen in figure 3 and table 6, the highest number of available contamination surveys occurred in 2003 (7,359 samples), with only a few hundred samples in 1998 and 2002. Only three contamination survey measurements exceeded the 100 mrem limit and occurred in 1996. Similar to the other TAs, none of the beta air samples exceeded the 100 mrem limit.

Figure 3. Total number of surface contamination surveys and air concentration monitoring results by year for TA-53

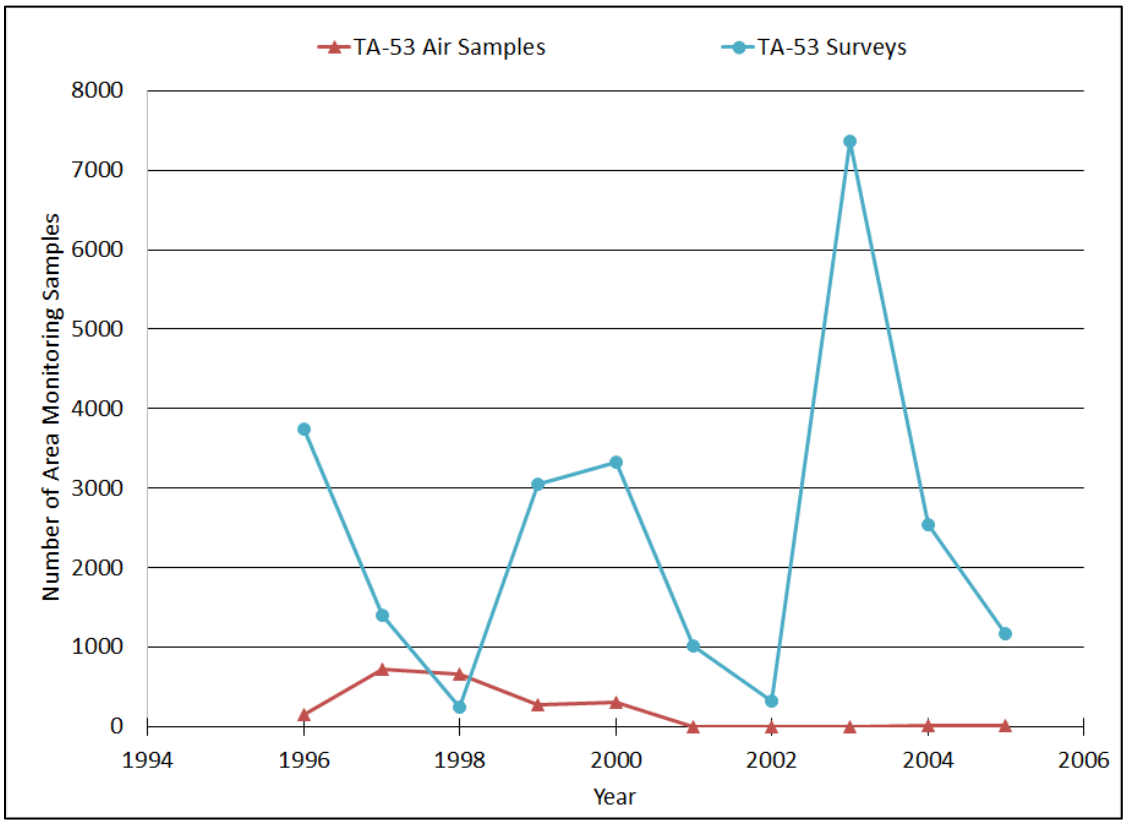


Table 6. Number of TA-53 surface contamination surveys exceeding administrative and 100 mrem limits by year

Year	Number of contamination surveys	Number exceeding administrative alpha limit (% of total)	Number exceeding 100 mrem alpha limit (% of total)	Number exceeding administrative beta limit (% of total)	Number exceeding 100 mrem beta limit (% of total)
1996	3,751	51 (1.4%)	3 (0.1%)	28 (0.7%)	0 (0.0%)
1997	1,408	12 (0.9%)	0 (0.0%)	8 (0.6%)	0 (0.0%)
1998	248	1 (0.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
1999	3,058	22 (0.7%)	0 (0.0%)	12 (0.4%)	0 (0.0%)
2000	3,330	14 (0.4%)	0 (0.0%)	5 (0.2%)	0 (0.0%)
2001	1,016	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
2002	331	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
2003	7,359	1 (0.0%)	0 (0.0%)	4 (0.1%)	0 (0.0%)
2004	2,540	8 (0.3%)	0 (0.0%)	2 (0.1%)	0 (0.0%)
2005	1,176	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Table 7 presents the number of air sampling results that exceed the 100 mrem limit. As shown in table 7 and figure 3, nearly all of the captured air monitoring records were from 1996 through 2000. The most observed air samples were in 1997 (729) with approximately 22 percent of those exceeding the 100 mrem limit for alpha. Also, in the previous year (1996), nearly one-third of the captured samples exceeded the 100 mrem limit for alpha. After these two years, the number

of alpha air samples exceeding the 100 mrem limit dropped below 10 percent. While over one-third of the alpha samples were above the 100 mrem limit in 2004, there were only eight captured samples for that year.

Table 7. Number of TA-53 air concentration samples exceeding the 100 mrem limit

Year	Air samples	Exceed 100 mrem alpha limit # (%)	Exceed 100 mrem beta limit # (%)
1996	160	53 (33.1%)	1 (0.6%)
1997	729	162 (22.2%)	12 (1.6%)
1998	660	35 (5.3%)	0 (0.0%)
1999	284	20 (7.0%)	0 (0.0%)
2000	308	15 (4.9%)	1 (0.3%)
2001	0	NA	NA
2002	0	NA	NA
2003	0	NA	NA
2004	8	3 (37.5%)	0 (0.0%)
2005	8	0 (0.0%)	0 (0.0%)

Observation 3: Air sampling data evaluated for Technical Area 53 during 1996 and 1997 showed the highest number of observed results that were above the 100 mrem limit (~33 percent and 22 percent, respectively). This was significantly higher than all other technical areas and years.

2.1.3.3 Examination of data by technical area and identified building

In addition to temporal trends by TA as discussed in section 2.1.3.2, SC&A parsed the data by building within each TA. Unfortunately, there was not enough granularity to parse the available data by building within each technical area *and* year. However, analysis by building may provide some insight into whether there are locations over the span of the evaluated period where the 100 mrem assumption may not necessarily be a bounding dose assignment.

In establishing the building associated with each sample result, some professional judgment was required by SC&A, though in some cases the area simply had to be classified as "Various." Table 8 shows the locations where contamination survey measurements were above the specified limits (100 mrem and/or administrative). Locations that did not have any contamination surveys above the specified limits are not included in table 8. As seen in the table, most locations with contamination surveys above the limits only showed a few percent of the total surveys for that specific location. However, Building 66 in TA-3 showed nearly one-third of the available survey measurements exceeded the administrative limit for alpha, but only ~1 percent of the contamination surveys in that location exceeded the 100 mrem limit for alpha. Per the LANL technical basis document (TBD), Building 66 was a press building and materials fabrication area (including a rolling mill) and also served as a thorium storage site (ORAUT, 2004, p. 12).

Table 8. Buildings within each technical area with surface contamination survey measurements above specified limits (1996–2005)

Technical area, building/location	# of survey results above specified limits	Number above administrative alpha limit (% of total)	Number above 100 mrem alpha limit (% of total)	Number above administrative beta limit (% of total)
TA-3, Building 29	5,610	275 (4.90%)	11 (0.20%)	0 (0.00%)
TA-3, Building 66	1,096	345 (31.48%)	14 (1.28%)	110 (10.04%)
TA-3, Various	2,372	42 (1.77%)	4 (0.17%)	2 (0.08%)
TA-48, Building 1	1,665	17 (1.02%)	1 (0.06%)	2 (0.12%)
TA-48, RC-1	6,504	40 (0.62%)	3 (0.05%)	52 (0.81%)
TA-53, 1-LSA	289	16 (5.54%)	2 (0.69%)	3 (0.88%)
TA-53, 3M	543	11 (2.03%)	0 (0.00%)	7 (1.29%)
TA-53, A Area	1,454	2 (0.14%)	0 (0.00%)	0 (0.00%)
TA-53, A-6	2,736	11 (0.40%)	0 (0.00%)	15 (0.55%)
TA-53, Aberdeen Steel	131	8 (6.11%)	0 (0.00%)	0 (0.00%)
TA-53, Blue Room	68	12 (17.65%)	0 (0.00%)	7 (10.29%)
TA-53, Counting Laboratory	378	1 (0.26%)	0 (0.00%)	0 (0.00%)
TA-53, ER-1	1,052	6 (0.57%)	0 (0.00%)	1 (0.10%)
TA-53, IPF	124	0 (0.00%)	0 (0.00%)	7 (5.65%)
TA-53, Line D	107	0 (0.00%)	0 (0.00%)	1 (0.93%)
TA-53, MPF-1	390	1 (0.26%)	0 (0.00%)	0 (0.00%)
TA-53, MPF-20	136	2 (1.47%)	0 (0.00%)	0 (0.00%)
TA-53, MPF-3	2,952	12 (0.41%)	1 (0.03%)	5 (0.17%)
TA-53, MPF-30	1,078	5 (0.46%)	0 (0.00%)	3 (0.28%)
TA-53, MPF-7	3,043	19 (0.62%)	0 (0.00%)	10 (0.33%)
TA-53, Various	3,225	3 (0.09%)	0 (0.00%)	0 (0.00%)

Note: there is no column detailing the number above the 100 mrem beta limit because they were all zero as shown in section 2.1.3.2.

Table 9 shows the locations where air sampling measurements were above the specified limits. Similar to the available contamination survey measurements, most locations with elevated samples were only a few percent of the total. The area designated as "A-6" had likely the most significant results with just above 10 percent above the 100 mrem limit. It is unclear if this location is a sublocation within the "A Area." Over 17 percent of instances in TA-53, where the air sampling exceeded the 100 mrem limit, did not have a specific building or location designation or were simply listed as "all locations." Not surprisingly, these entries were in the late 1990s, which is consistent with the evaluation discussed in section 2.1.3.2 and observation 3.

Table 9. Buildings within each technical area with air sampling measurements above 100 mrem limit (1996–2005)

Technical area, building/ location	# of air sampling results above specified limits	Number above 100 mrem alpha limit (% of total)	Number above 100 mrem beta limit (% of total)
TA-3, Building 29	63,350	197 (0.31%)	0 (0.00%)
TA-48, Building 1	492	13 (2.64%)	0 (0.00%)
TA-48, RC-1	2,713	16 (0.59%)	0 (0.00%)
TA-53, Building 29	19	1 (5.26%)	0 (0.00%)
TA-53, Building 394	32	1 (3.13%)	0 (0.00%)
TA-53, Building 7	72	5 (6.94%)	0 (0.00%)
TA-53, 1-LSA	3	2 (66.67%)	0 (0.00%)

Technical area, building/ location	# of air sampling results above specified limits	Number above 100 mrem alpha limit (% of total)	Number above 100 mrem beta limit (% of total)
TA-53, 3M	246	10 (4.07%)	0 (0.00%)
TA-53, A Area	18	1 (5.56%)	0 (0.00%)
TA-53, A-6	94	10 (10.64%)	2 (2.13%)
TA-53, LANSCE	287	22 (7.67%)	0 (0.00%)
TA-53, Not specified	1,349	236 (17.49%)	12 (0.89%)

2.1.4 RPRT-0101 evaluation of the radiological control program

As part of its weight-of-evidence argument, RPRT-0101 provides documentation and selected examples to illustrate how the radiological control program was set up to conform with the requirements of 10 CFR Part 835 and also to provide evidence that the program was in fact functioning as intended by site procedure. The main examples of engineering and area monitoring controls are described as facility design, laboratory hoods/gloveboxes, hot cells, use of shielding, and use of appropriate ventilation. In citing these concepts, RPRT-0101 points to portions of the 1994 RadCon Manual for LANL, provided via email by the site (Hoover, 2021a). SC&A confirmed that many, but not all, of these engineering and monitoring controls are as listed in section 2.1 of RPRT-0101. However, the 1994 RadCon Manual excerpts do specify the contamination procedures as detailed in section 2.3 of RPRT-0101.

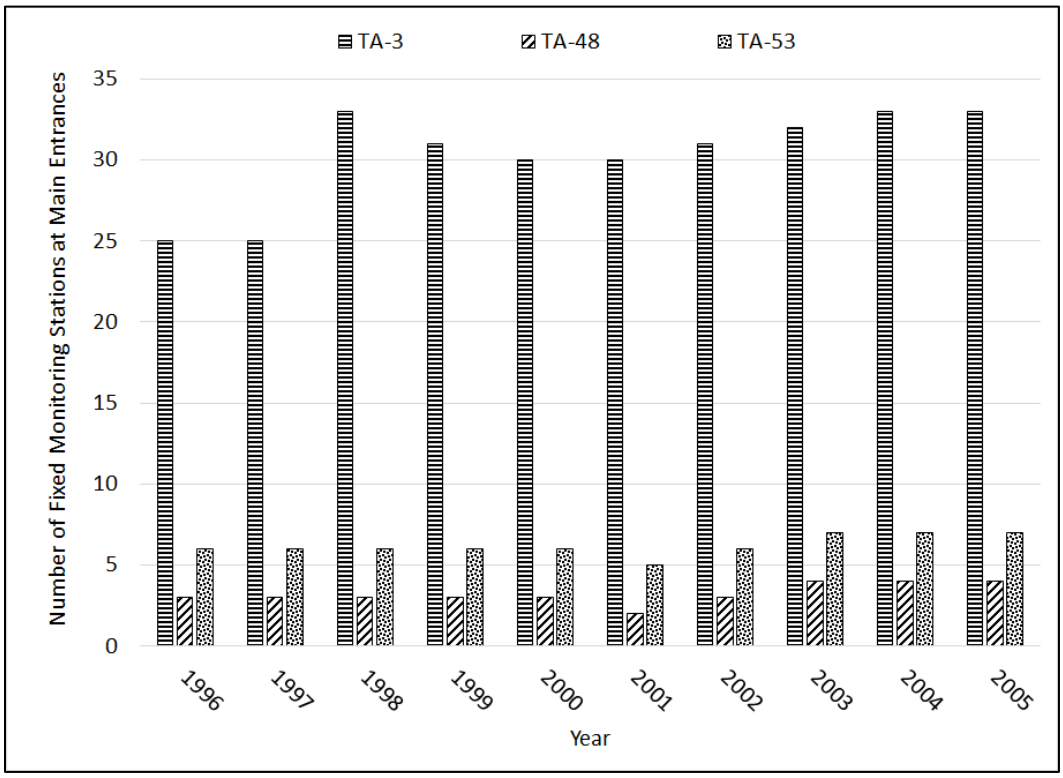
Section 2.2 of RPRT-0101 provides examples from the three evaluated TAs to demonstrate that instructions were in place to delineate surveying responsibilities for the radiological control technicians (RCTs) and continuous air monitoring procedures. The examples were provided in routine monitoring instructions (RMIs) that were dated as taking effect at the following times:

- TA-3: January 2000, March 2004, and unknown month 2005
- TA-48: July 1997 and March 2000
- TA-53: February 2005

SC&A reviewed the references cited in section 2.2 of RPRT-0101 and concurs that they include the appropriate procedural instructions as described in RPRT-0101 for control of both airborne and surface contamination. However, SC&A also notes that, except for the RMI for TA-48 in 1997, the example RMIs are from the middle or latter part of the evaluated SEC period (i.e., 2000 and on).

Section 2.3.2 of RPRT-0101 describes the radiation instrumentation available at the site, including fixed detectors (i.e., personal contamination monitors and hand and foot monitors) at dedicated entrances to facilities including TA-3, TA-48, and TA-53. This information was provided in a 2021 letter from LANL DOE (Hoover, 2021b) and includes the calibration date range, which is assumed to reflect the instrument's operational period. Figure 4 shows the number of such instruments for the facilities evaluated. As seen in the figure, the number of fixed monitoring stations at TA-3 was significantly more than at the other areas, and the majority of these stations (~92 percent) were associated with the CMR.

Figure 4. Number of fixed monitoring stations at dedicated entrances by calibration years



Section 2.3.2 of RPRT-0101 also provides examples of incident reports involving the fixed monitoring stations. These examples include incident reports from 1996 (i.e., the start of the period under evaluation); however, inspection of the 1996 reports show that they are all from TA-55 (a plutonium facility) and likewise identify plutonium as the contaminant of interest. Therefore, they may be of limited relevance when discussing facilities that handled exotic radionuclides.

Finding 3: Examples of routine monitoring instructions intended to demonstrate contamination surveying and air monitoring responsibilities were dated as taking effect in the year 2000 or later (except for the one for TA-48, which was effective July 1997). Additionally, examples of incidents in 1996 with fixed monitoring stations used to control contamination at location entrances were for TA-55, which is the plutonium facility and may not be representative of the facilities where exotics were handled.

2.1.5 Conclusions about RPRT-0101

As discussed in section 4.0 of RPRT-0101, RPRT-0101 is designed to create a weight-of-evidence argument for assigning 100 mrem for internal exposures to exotic materials for those who were not monitored. However, SC&A questions whether this would also apply to workers who should have been monitored (and were not) or workers who were monitored, but for whom records are unavailable for a variety of reasons (e.g., records were lost, destroyed, improperly associated with the given worker, etc.). In these cases, co-exposure intakes are generally warranted. Such situations should be clarified by NIOSH and discussed by the work group (observation 1).

RPRT-0101 notes, and SC&A agrees, that the report was not based on a complete dataset either by location or by year, and the level of completeness is unknown. Furthermore, the captured and transcribed dataset was not meant to be evaluated by any established statistical measure, as it is not considered a random or a representative sample of the contamination survey and air sampling data (findings 1 and 2).

Inspection of the underlying dataset by SC&A appears to indicate that several duplicate entries were identified in the transcribed dataset. In many cases, these duplicate samples were removed; however, it appears in some cases they were included in the evaluated data (observation 2). SC&A notes that removal of these duplicate samples would likely have minimal (if any) effect on the resulting analysis and conclusions.

When parsing the available dataset by year and general TA, nearly all instances showed that 1 percent or less of the data were above the 100 mrem modeled limitation. However, TA-53 in 1996 and 1997 showed that ~33 percent and 22 percent were above the 100 mrem limit. Unfortunately, the building/location-specific analysis in section 2.1.3.3 of this report did not provide further information on these years because the underlying air sampling reports did not specify a location within TA-53. It may be worth further discussion and investigation to determine if the 100 mrem limit is sufficiently bounding for this TA and year (observation 3).

Finally, RPRT-0101 provides several examples of RMIs to demonstrate the procedural requirements for routine contamination surveys and air sampling. However, with the exception of TA-48, these procedures were dated to take effect in the year 2000 or later. Additionally, examples of fixed monitoring stations used to control the spread of contamination were reflective of the plutonium facility, at least in 1996 (finding 3). Neither set of examples applies to TA-53 in the early years, where somewhat elevated contamination surveys and air sampling were observed.

2.2 Examination of plutonium radiation work permits (RPRT-0102)

Section 2.2 reviews RPRT-0102 in the context of the entirety of the internal dose reconstruction issues at LANL during the period 1996–2005. This section is split into six main subsections:

- 2.2.1: Purpose, scope, and conclusions of RPRT-0102
- 2.2.2: SC&A comments on general co-exposure formulation
- 2.2.3: SC&A comments about regulatory compliance
- 2.2.4: Review of health physics checklist and Bioassay Enrollment, Scheduling, and Tracking (BEST) system
- 2.2.5: Review of radiological work permit plutonium monitoring compliance
- 2.2.6: Conclusions about RPRT-0102

2.2.1 Purpose, scope, and conclusions of RPRT-0102

NIOSH delivered ORAUT-RPRT-0102, "Assessment of Los Alamos National Laboratory Plutonium Bioassay Programs 1996 to 2001" (ORAUT, 2021), in December 2021. The report was designed to evaluate the feasibility of developing a plutonium co-exposure model to be

applied to (1) unmonitored workers who likely should have been monitored and (2) partially monitored workers. Of particular importance are the completeness and representativeness of the available dataset used in producing co-exposure estimates. The concepts of completeness and representation are outlined in the implementation guidance document, DCAS-IG-006, revision 00, "Criteria for the Evaluation and Use of Co-exposure Datasets" (NIOSH, 2020).

One specific issue raised in the 1999 LANL self-assessment (reported as NC ID 484) was LANL's compliance with the internal monitoring requirements specified on RWPs. That independent audit of the site found that in at least one instance, two of five workers who signed in on a plutonium RWP were not appropriately bioassayed for plutonium (Brackett & La Bone, 1999, PDF p. 6). In addition, the 1999 auditors noted that workers from Johnson Controls (the construction and maintenance contractor for LANL) were not being appropriately enrolled in the bioassay program (and thus were not being sampled) (Brackett & La Bone, 1999, PDF pp. 6–7). The work group requested that NIOSH undertake a sampling of RWPs and assess the degree to which workers were appropriately submitting the required bioassay based on their associated RWPs.

To characterize and gain perspective on the overall operation and coverage of the plutonium bioassay program during the period of interest (1996–2001), NIOSH examined health physics checklists (HPCs), which were the mechanism by which requests were made for individual work to be enrolled in the routine internal monitoring program (in vitro and/or vivo). Once enrolled, the worker would be entered into the BEST system, where the actual bioassay requests were tracked. NIOSH compared these two databases along with available plutonium internal monitoring to determine the extent to which workers who were enrolled via the HPC process were included in BEST and ultimately submitted the required bioassay samples.

However, as was noted during the 1999 LANL self-assessment, the auditors found that HPCs were not always submitted appropriately by some contractors (specifically Johnson Controls, LANL's construction and maintenance contractor) (Brackett & La Bone, 1999). It must be noted that the RWP mechanism for collecting and analyzing appropriate bioassay is independent of the HPC/BEST procedures; thus, the potentially incomplete nature of the HPC process does not affect the conclusions based on an analysis of the RWPs.

Ultimately, the RWP sampling exercise was meant to mimic a similar analysis that was performed for SRS and is documented in ORAUT-RPRT-0092, "Evaluation of Bioassay Data for Subcontracted Construction Trade Workers at the Savannah River Site" (ORAUT, 2019). As part of that effort, RWPs for the years 1991–1997 were selected in a semirandom fashion until a sufficient number of RWP-worker combinations were identified for each relevant area and timeframe. However, instead of performing such a sampling for LANL, NIOSH instead elected to perform a full analysis of all available RWPs, thereby eliminating the potential for any unintentional bias that may be injected through a partial sampling of the RWPs. The design and execution of the evaluation of RWPs is described in sections 3.0, 5.6.1, and 10.0 of RPRT-0102.

A third facet of NIOSH's evaluation analyzed the relative exposure potential for four main groups of workers (or strata): Nuclear Materials Technology (NMT), Environmental Safety and Health (ESH), Johnson Controls, and all other monitored workers. The results of this comparison

showed the most frequently monitored groups (NMT and ESH) also had the highest results for plutonium (Pu)-238 and generally higher results for Pu-239.

Finally, section 2.0 of RPRT-0102 presents the general principles and formulation of co-exposure models and is discussed in section 2.2.2 of this report. Section 4.0 of RPRT-0102 discusses regulatory compliance in the context of the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) program and co-exposure modeling; SC&A's comments about this discussion can be found in section 3.4 of this report.

Based on the totality of analysis and discussion in RPRT-0102, NIOSH came to the following general conclusions:

1. Workers who submitted HPCs were correctly enrolled in the bioassay program via the BEST system nearly 100 percent of the time.

2. Bioassay requests submitted and tracked in the BEST system were fulfilled approximately 86 percent of the time.

3. Available in vitro bioassay data were requested and tracked via the BEST system approximately 94 percent of the time.

4. A significant proportion of workers who signed acknowledgement forms contained in RWPs were appropriately monitored for plutonium.

5. No evidence was identified to suggest that workers from any major organization were systemically noncompliant with bioassay requirements as specified on the RWPs.

6. Ninety-seven percent of RWPs reviewed showed that at least half of the workers who signed the acknowledgement form were appropriately monitored for plutonium.

NIOSH's overall conclusion is as follows:

> The preponderance of evidence supports the conclusion that the plutonium bioassay data reported by LANL in the 1996 to 2001 study period include a significant portion of the most highly exposed workers and are therefore adequate to construct a co-exposure model for plutonium. [ORAUT, 2021, p. 29]

2.2.2 SC&A comments on general co-exposure formulation (RPRT-0102, section 2.0)

As stated in the previous section, section 2.0 of RPRT-0102 discusses the general principles and formulation of co-exposure models. Included in this discussion is the basic concept that co-exposure models are generally either representative or biased toward higher monitoring results. In representative co-exposure models, the population of monitored workers used in formulating the model would be based on a random sample of the monitored workforce. Inherent in this example is that the monitored workforce is assumed to be a random subset of the full exposed workforce. In biased co-exposure models, the assumption is that the given site focused their monitoring program on the higher exposed workers and thus any random sample pulled from that population would have generally higher results than the exposed worker population as a whole. RPRT-0102 notes that such assumptions are predicated on the existence of a dataset

(referred to as a "study sample" in the report) in which a "significant portion of the most highly exposed workers in the target population are monitored" (ORAUT, 2021, p. 8). The report goes on to state:

> Note that all of those workers do not need to have been monitored, just a significant portion of them. . . .
>
> In summary, a representative or bounding co-exposure model can be constructed unless a significant portion of the most highly exposed workers were not monitored or do not appear in the study sample. [ORAUT, 2021, pp. 8–9]

These concepts are more fully discussed in DCAS-IG-006 (NIOSH, 2020), which uses the terms "completeness" and "representative" in evaluating the degree to which a given coworker model is deemed sufficient to reconstruct internal doses. Specifically, DCAS-IG-006 provides the following concerning the completeness and representativeness of the available dataset intended to form the basis of co-exposure estimates:

> the amount of available monitoring data must be evaluated to determine if there are sufficient measurements to ensure that the data are either bounding or representative of the exposure potential for each job/exposure category at the facility. . . . the available monitoring data should be reviewed against the number and types of workers that were involved in radiological activities over time at the facility. [NIOSH, 2020, p. 6]

In general, SC&A agrees with this characterization of the purpose of co-exposure studies as presented in section 2.0 of RPRT-0102. Specifically, if it can be established that the highest exposed workers were monitored, or, alternately, a representative portion of the exposed population were monitored *and* that data are available for analysis, then a sufficiently accurate and claimant-favorable co-exposure model is likely feasible. Furthermore, if it is established that the available dataset does not sufficiently represent the highest exposed worker population, then any subsequent co-exposure estimate is likely to underestimate the unmonitored exposures for at least some workers. In such cases, a sufficiently accurate co-exposure model is likely not feasible.

However, it is important to note that an acceptable level of completeness and the degree to which the data are sufficiently representative of the unmonitored population is currently a subjective decision and a matter of professional judgment. For example, an SEC class was recently recommended by the Board and designated under SEC-0103 for subcontract workers because it was determined by the Board that RWP-based monitoring was sufficiently incomplete to formulate an appropriately representative co-exposure estimate for that population despite a significant amount of routine monitoring data available. Currently, the SEC Issues Work Group is undertaking the issue of subjective decisions on completeness and representation to determine if there is a way to quantify the evaluations consistently throughout the program. However, that work has not been completed to date, so it is not clear at this time if a standard objective measure of completeness and representation is feasible.

2.2.3 SC&A comments about regulatory compliance (RPRT-0102, section 4.0)

Section 4.0 of RPRT-0102 discusses regulatory compliance with 10 CFR Part 835 in the context of the EEOICPA program and co-exposure modeling feasibility. In general, RPRT-0102 argues that co-exposure modeling and regulatory compliance issues are mutually exclusive in that complete regulatory compliance is not necessary to formulate a suitable co-exposure model to reconstruct doses. Specifically, RPRT-0102 states:

> In fact, regulatory compliance with participation in a bioassay program is neither necessary nor sufficient to construct a co-exposure model from the data from that program. . . .
>
> compliance with the regulations in place at the time the radiological work was performed is not required in order to perform a dose reconstruction or develop a co-exposure model. [ORAUT, 2021, p. 10]

RPRT-0102 (p. 10) provides three examples of how there could be regulatory compliance issues that have no bearing on the ability to construct a suitable co-exposure model. These examples can be summarized as follows:

1. No workers submit bioassay samples because it is determined that it is unlikely that any of the exposed workforce will exceed 100 mrem CEDE in a given year. In this case, a traditional co-exposure model is not possible because there are no data on which to base it.

2. Workers are on a routine monitoring program; however, circumstances indicate that the worker was never actually exposed. Therefore, regardless of whether that worker submitted a sample or not, a co-exposure model based on the actual exposed population could be considered bounding of the unmonitored worker. The incompleteness in this case has no effect on the subsequent model because the missing sample represents no exposure.

3. A worker was exposed to significant levels of internal radiation but did not submit a sample. However, this should not affect the veracity of a subsequent co-exposure model because a significant portion of the most highly exposed workers are monitored.

SC&A does not materially disagree with any of these examples. SC&A believes the most compelling example for this discussion is the third item, in which a worker was exposed and not sufficiently monitored. While SC&A agrees this does not summarily obviate the ability to construct a suitable co-exposure model, the assumption is made that the incomplete portion of the dataset is sufficiently represented by the complete portion. In the context of RPRT-0102 analysis and discussion, the purpose was to establish the level of incompleteness and inform the work group as to (1) what data might be missing, (2) what exposure potential is represented by that unmonitored subset, and (3) whether those missing or incomplete data render the available data not sufficiently representative for use in DR. The regulatory noncompliance indicated that, at least in one instance, 40 percent (2 of 5) of the workers on a given RWP were not monitored properly. As SC&A noted in section 2.2.2, the level of incompleteness and its effect on representation is a subjective judgment to be made by the Board.

Section 3 of this report further discusses section 4.0 of RPRT-0102 and these issues from a programmatic standpoint.

2.2.4 Review of health physics checklist and BEST system

2.2.4.1 Summary of BEST analysis

To evaluate the extent to which established bioassay requests for plutonium were fulfilled and those data are available for co-exposure analysis, RPRT-0102 compared the plutonium bioassay requests in BEST to the available electronic in vitro bioassay dataset. NIOSH found that out of the 13,895 plutonium bioassay requests during the period of interest, approximately 85.7 percent (11,914 total) were appropriately fulfilled. Section 2.2.4.2 of this report discusses the reasons that individual sample requests were not fulfilled. Table 10 shows the results by year. As seen in the table, the number of plutonium bioassay requests remained somewhat consistent, though it is interesting that the number that went unfulfilled increased significantly (more than doubled) between the periods 1996–1998 and 1999–2000.

Table 10. Summary by year of BEST plutonium bioassay requests and fulfillments

Year	Number of bioassay requests	Number fulfilled bioassay requests	Number unfulfilled bioassay requests	Percent compliance with BEST bioassay requests
1996	2,012	1,827	185	90.8%
1997	2,012	1,857	155	92.3%
1998	2,450	2,230	220	91.0%
1999	2,360	1,908	452	80.8%
2000	2,818	2,245	573	79.7%
2001	2,243	1,847	396	82.3%
All years	13,895	11,914	1,981	85.7%

In addition, RPRT-0102 presents compliance with BEST based on the three largest employer categories (Johnson Controls, KSL Services, and specifically delineated LANL staff). Table 11 summarizes these results. Interestingly, the percentage of fulfilled bioassay requests, as documented in the BEST system, generally decreased between 1998 and 1999 for all employer categories. The lowest compliance percentage (~45 percent) was for Johnson Controls, one of the site's maintenance contractors, in 2001. However, this only represented 29 total requests. KSL Services took over LANL's maintenance contract beginning in 2003; SC&A assumes that KSL Service employees performed similar maintenance duties during the years of interest.

Table 11. Total number of plutonium bioassay requests and percent compliance by main employer and year

Year	LANL	KSL Services	Johnson Controls	All other entries
1996	1,212 (93.2%)	256 (93.4%)	128 (78.1%)	416 (86.3%)
1997	1,200 (94.2%)	242 (93.4%)	119 (82.4%)	451 (89.4%)
1998	1,650 (93.8%)	262 (86.6%)	98 (65.3%)	440 (89.1%)
1999	1,712 (79.6%)	172 (82.6%)	37 (56.8%)	439 (87.0%)
2000	2,207 (78.3%)	187 (87.7%)	43 (67.4%)	381 (85.3%)
2001	1,651 (82.1%)	246 (87.4%)	29 (44.8%)	317 (83.0%)
All years	9,632 (85.7%)	1,365 (88.9%)	454 (71.6%)	2,444 (86.9%)

Observation 4: The lowest observed compliance with bioassay requests via the BEST system was for Johnson Controls, one of LANL's maintenance contractors, which had a low of ~45 percent compliance for 29 requests in 2001 (~72 percent compliance for all years). However, KSL Services, which appears to have been another maintenance contractor for LANL, had the highest rate of compliance observed overall (~89 percent) and was never lower than ~83 percent.

Finally, NIOSH also did a reverse comparison in which the in vitro dataset was back compared to the BEST database to establish if the observed bioassay result was requested through the HPCs and subsequent entry into BEST. This was meant to establish that the BEST system was the primary method by which workers were enrolled in the plutonium program, sample requests were made, and the submission of the requested samples were tracked. NIOSH concluded that almost 94 percent of available in vitro data could be traced back to requests made via the BEST system. For the 6 percent of available in vitro data that could not be traced directly to BEST, NIOSH postulated the following:

> Indications are that samples lost in process due to problems like low recovery were reported and the kit number was removed from BEST. This could explain some of the instances where a plutonium result in the in vitro dataset could not be traced back to BEST. [ORAUT, 2021, p. 20]

SC&A's examination of the BEST database confirms that no sample requests were identified during the period of interest where a low recovery was specifically indicated as an issue. However, sample requests outside of the period of interest sometimes indicated "low recovery" in the remarks column, which provides some evidence to support NIOSH's hypothesis.

In addition, it is apparent from figure 6-1 of RPRT-0102 that bioassays as a result of RWP requirements would not necessarily have required submission of an individual HPC and inclusion in the BEST database. It is possible that these job-specific bioassays further explain the difference between the in vitro dataset totals and the bioassay requests made via the BEST system.

2.2.4.2 Characterization of unfulfilled bioassay requests in BEST

Section 7.0 of RPRT-0102 notes that out of 13,895 total bioassay requests shown in BEST, approximately 85.7 percent were fulfilled (11,914 total). NIOSH continues: "Of the 1,981 samples not received, 1,613 have legitimate reasons for not being received" (ORAUT, 2021, p. 18).

Put another way, NIOSH contends that only ~2.6 percent of bioassay requests made through BEST were actually delinquent. In table 7-1, NIOSH further breaks down the reasons provided for the requested sample not being received (this information is reproduced here as table 12 for convenience). Based on the numbers highlighted by NIOSH, SC&A assumes that the only categories characterized by NIOSH as not constituting "legitimate reasons" are the categories of "None given" and "No sample submitted."

SC&A does not agree with this characterization. Whether or not there is a documented reason for the missing sample, SC&A believes the only "legitimate" reason to excuse a sample request not being fulfilled is a complete change in exposure potential occurring immediately after the

previous sample. For example, if a worker did not submit a sample because they were on travel (one instance), that sample should have been collected upon return. SC&A believes similar criteria should apply to the following categories that constitute 42 total missed bioassay results: "Vacation," "Holiday break," "Sick leave," and "Extended leave of absence."

Furthermore, SC&A does not believe that a faulty sample or inadequate administrative information should be considered a legitimate reason for the bioassay result to not have been submitted. These categories would include "Label/seal problems," "Lost kit," and "No charge," which constitute 120 total missed bioassay samples. It is not known what reasons constitute the "Miscellaneous" category (94 total missed bioassay samples); therefore, it is questionable to assume that the reasons are legitimate.

Sample requests that were not submitted because the EE was no longer employed at the site (i.e., "Terminated") do not address whether the EE submitted a termination sample. If the EE submitted a termination sample, then the EE's monitoring could be considered complete and the sample request in BEST would no longer be valid. However, if the EE did not submit a termination sample, then logically there was an unmonitored period for that worker who was intended to be monitored and was not. In this scenario, SC&A does not feel the missing bioassay is for a legitimate reason.

Table 12. Documented reasons for bioassay requests in BEST going unfulfilled

Reason	Number of samples not submitted
Travel	1
Vacation	1
Label/seal problems	4
Holiday break	5
Change of station	6
Sick leave	10
None given	17
Extended leave of absence	25
Lost kit	37
No charge	79
Miscellaneous	94
No longer in area	115
Monitoring no longer required	175
Terminated	203
No sample submitted	351
Inactivated for migration	858
Total	1,981

Source: ORAUT (2021), p. 19, table 7-1.

In a parallel situation, if a worker no longer performed radiological work requiring plutonium monitoring (the categories "No longer in area" and "Change of station"), this would be legitimate if that worker submitted a bioassay sample at the end of work in the radiological area. In this way, it is akin to the EE being "Terminated" from radiological work, and the missing bioassay could be considered legitimate. However, if the EE continued work for some portion of the intended monitoring period within the radiological area, then this would constitute an

unmonitored timeframe; SC&A does not believe the missing bioassay result can be considered legitimate.

RPRT-0102 defines the category "Inactivated for migration" as follows:

> Note that INACTIVATED FOR MIGRATION refers to sample requests that were canceled to migrate BEST to a new database. [ORAUT, 2021, p. 18]

However, no information is provided as to whether the migrated bioassay requests were then fulfilled based on the new database. Therefore, it is difficult to judge whether those could be considered legitimate reasons, as it has not been established if the bioassay sample request actually went unfulfilled.

SC&A assumes that "Monitoring no longer required" means that, for the entirety of the given monitoring period, the EE was no longer exposed to plutonium. In this narrow case, SC&A would agree that the missing bioassay sample is legitimate. However, if some portion of the intended monitoring period did require monitoring, SC&A would have similar concerns as for the "Terminated," "No longer in area," and "Change of station" categories.

Observation 5. SC&A does not agree with NIOSH's contention that the large majority of unfulfilled bioassay requests (1,613 of 1,981) were for legitimate reasons (i.e., over 97 percent of bioassay requests were either correctly fulfilled or have legitimate reasons for going unfulfilled). It is SC&A's opinion that the only legitimate reason for an unfulfilled bioassay request is that the EE was not exposed to plutonium for the entirety of the intended monitoring period.

2.2.5 Review of radiological work permit plutonium monitoring compliance

2.2.5.1 Summary and review of RPRT-0102 RWP assessment results

Section 10.0 of RPRT-0102 gives the results of an assessment of worker compliance with RWP-mandated plutonium bioassay. In a general sense, the measure of compliance is a simple percentage: what percentage of workers who were mandated to submit plutonium bioassay based on RWP work actually submitted the appropriate bioassay. However, two main questions must be answered and assumptions must be made in determining what constitutes appropriate worker monitoring compliance. These two questions are:

1. What is an appropriate timeframe between the RWP work and the submission of a plutonium sample?
2. How many RWPs for a given worker during a given year should have appropriate bioassay sampling to be considered compliant?

To answer question 1, NIOSH developed the following criteria for what RPRT-0102 (p. 26) refers to as the "time window for [bioassay] submission." NIOSH determined that a worker would be deemed compliant with the plutonium-monitoring requirements if a bioassay sample was submitted at some point either during the performance of the RWP (i.e., prior to the RWP expiration date) or after the expiration date of the RWP but within the year subsequent to the year in which the RWP work was performed. Section 2.2.5.2 of this review further discusses the time window for bioassay submissions.

In addition to the time window for bioassay submission, NIOSH evaluated the RWP and bioassay data considering no limit on when a subsequent plutonium sample was submitted. This second evaluation (referred to in RPRT-0102 (p. 26) as the "open window" compliance percentage) is a useful metric for determining if EEs working under an RWP with plutonium bioassay requirements were ultimately sampled and thus would have their exposures represented in any subsequent co-exposure model. This metric does not consider whether the RWP-based plutonium bioassay program was functioning properly but rather focuses on the end result in the context of co-exposure modeling alone.

The second main question asks what constitutes individual worker compliance on an annual basis (e.g., is monitoring compliance with one of two RWPs in a year considered compliant or noncompliant). To address this question, NIOSH performed two separate analyses, one that considered an individual RWP-worker combination as a distinct event and another that combined all RWP-related work for a given individual over a year. RPRT-0102 refers to the former analysis as the "work" metric[6] and the latter analysis as the "worker" metric.

Regarding the worker metric, in which all RWPs for an individual worker are considered in a given year, RPRT-0102 provides the following explanation and example:

> It is also important to examine if the worker was in compliance with the monitoring requirements for that year with no consideration of the number of acknowledged RWPs. There is no unique way to define this measure. In this report, measuring compliance by a worker is determined by checking compliance with any of the acknowledged RWPs that year. For example, if a worker signed 10 RWPs and was in compliance (in terms of work) with nine of them, then the worker was in compliance for the year. Using this measure puts equal weight on each worker when calculating compliance with the monitoring program. [ORAUT, 2021, p. 26]

SC&A recognizes the merits of analyzing the data by individual worker over several RWPs to eliminate the inherent effect of the job-specific analysis in which an individual worker may have signed acknowledgment forms for several RWPs during a given year and thus would count multiple times in the job-specific analysis. Thus, workers who performed work under multiple RWPs would have unequal weight compared to those workers who may have only worked under one RWP in a given year.

In a corollary situation, such unequal weight was identified as an issue in co-exposure modeling in which a few workers submitted significantly more bioassay samples than other workers in the exposed population. This facet of co-exposure modeling is referred to as "data dominance" and was dealt with by developing the time weighted one-person-one-statistic (TWOPOS) methodology for analyzing bioassay data. The TWOPOS methodology averages each bioassay

[6] For the purposes of this report, SC&A refers to the "work" metric as the "job-specific" analysis, as it refers to a single worker on a single RWP as the datapoint of interest rather than the collection of RWPs an individual worker may have been involved in during a given year.

result for a given worker and timeframe to obtain a single value, thus obviating any issues with an individual EE being more heavily weighted in subsequent analyses of a cohort of workers.

Therefore, SC&A agrees that an individual-specific metric (as opposed to an individual-job combination metric) is warranted. However, SC&A does not agree that the individual worker compliance should be defined as "measuring compliance by a worker is determined by checking compliance with **any** of the acknowledged RWPs that year" [emphasis added]. By that RPRT-0102 logic, a worker who signed acknowledgment forms for 10 RWPs and was compliant with the bioassay requirement for 1 of 10 RWPs is considered compliant.

Finding 4: SC&A does not agree that an individual worker should be considered compliant with RWP bioassay requirements if ANY of the RWPs associated with that individual during the year have appropriate associated plutonium bioassays.

It is important to note that this particular individual worker-related compliance metric is only relevant when considering the assumed acceptable time window and does not affect the open window analysis in which it is determined whether the exposed workers would be represented in the co-exposure model. RPRT-0102's evaluation of RWP-mandated bioassay compliance is shown in table 13.

As seen in table 13, the compliance estimates decrease when considering individual workers as a whole rather than the worker-RWP connection. However, in the greater context of co-exposure modeling, the open window statistics are of particular import to the Board and show rates ranging from ~81 percent to 99 percent compared to job-specific guidance (~75 percent to 98 percent when considering individual workers). Whether these percentages of bioassay compliance are acceptable when constructing co-exposure models is a matter of policy and should be considered by the Board.

Table 13. Summary of RWP bioassay compliance results in RPRT-0102

Worker group	Number of workers	Number of RWPs	Percent of job-specific compliance within assumed window	Percent of worker-related compliance within assumed window	Percent of job-specific compliance assuming open window	Percent of worker-related compliance assuming open window
Johnson Controls	703	1,396	81.0	65.1	92.6	83.5
Environmental Safety and Health	227	2,128	96.5	84.1	98.1	87.8
Nuclear Materials Technology	660	1,393	97.1	95.3	99.0	98.2
Other employment group	556	579	70.6	63.3	81.4	74.5

2.2.5.2 Assumption about appropriate time window for submission of bioassay

As described in section 10.0 of RPRT-0102, it is necessary to establish an acceptable timeframe for submission of RWP-related bioassay to establish compliance with the RWP monitoring requirement. RPRT-0102 describes this as the "time window for submission" and defines it as

any plutonium sampling occurring during the actual RWP work (i.e., between the effective and expiration date of the RWP) or alternately "By the end of the year after the year in which the RWP expired . . . (the post-RWP sampling window)" (ORAUT, 2021, p. 26).

SC&A disagrees with these assumptions about what constitutes compliant RWP-based monitoring. The LANL bioassay program frequency is outlined in attachment A of the LANL internal dose TBD, which provides information for 1973–1997 and 1998 onward (ORAUT, 2013, p. 94). This information is summarized here in table 14.

Table 14. Plutonium monitoring frequency information provided in LANL occupational internal dose technical basis document

Frequency of monitoring	1973–1997	1998 onward
Monthly	Not established; instructions for monthly monitoring appear prior to this year	Not established; instructions for monthly monitoring appear prior to this year
Quarterly	Not specifically discussed in TBD though mentioned under biannual sampling frequency (refer to next row)	Not specifically discussed in TBD
Biannual	1. Persons working with Pu but ≤10 g Pu-239 or ≤0.04 g Pu-238 in chemical or metallurgical operations, 2. Supervisors of the quarterly sampled category, or 3. Persons with >10,000 pCi body burden but <20,000 pCi	1. Working with ≥0.04 g (0.7 Ci) of Pu-238, analyzed by RAS 2. Performing metallurgical operations or maintenance on systems containing ≥10 g of Pu-239 or Pu-240 and ≥0.04 g of Pu-238 (0.6–0.8 Ci) analyzed once by TIMS and RAS and once by RAS
Annual	1. Supervisors, persons working with sealed containers of Pu, 2. Casual encounters with Pu, or 3. Working with prepared counting foils containing >20 mg of Pu-239 or 0.08 mg of Pu-238 (~1.3 mCi of either)	1. Routine work with operations of <10 g (0.6 Ci) of Pu-239 or Pu-242 (0.6–0.8 Ci) 2. Performing maintenance on systems containing ≥10 g of Pu-239 or Pu-240 (0.6–0.8 Ci) analyzed by TIMS and RAS 3. Working with operations of or performing maintenance on systems with <0.04 g of Pu-238 4. Line supervisors of personnel in semiannual categories 5. Transuranic glovebox, bag outs, etc. 6. ESH-1 RCTs who frequently enter work areas 7. All personnel with confirmed measurable intakes of Pu-238 and/or Pu-239
Termination	1. Persons terminating employment who have previously submitted urine samples, or 2. Have been working in major plutonium areas, but never sampled	Workers who submitted routine samples

As seen in the table, the minimum frequency for submission of plutonium urinalysis samples for routinely monitored workers was on an annual basis. All RWPs and workers analyzed as part of RPRT-0102 were part of the plutonium access list (PAL); therefore, it is logical that each would be required to submit an annual plutonium sample. SC&A believes that extending the window for acceptable submission into the "end of the year after the year in which the RWP expired" is inappropriately expansive.

As an extreme illustrative example, consider an RWP that expires in January 1996. The workers who signed the acknowledgement form for that RWP would be considered compliant with the bioassay requirements if they were sampled by the end of December 1997 (essentially a 23-month window). SC&A believes a maximum time window for submission of bioassay samples is 1 year after the expiration of the RWP (or effectively the last potential day of radiological work under the permit). In the previous example, workers would be required to submit plutonium bioassay samples by the end of January 1997 (i.e., 12 months post radiological work).

Similarly, SC&A does not find that submitting a plutonium bioassay sample at some point *during* the RWP work is sufficient to characterize the entirety of the work under that RWP (i.e., the exposures occurring after the sample taken mid-RWP would not be captured). However, it is important to point out that if workers were on an annual plutonium bioassay schedule and submitted a sample at some point during the RWP work, then the next annual sample would logically fall within a 1-year window from the expiration of the RWP. Thus, the worker could be considered compliant unless a subsequent sample was not submitted within 1 year of the RWP expiration date.

Finding 5: SC&A does not believe the NIOSH assumption that an appropriate time window for bioassay submission of during the RWP work or by "the end of the year after the year in which the RWP expired" is an appropriate metric for assessing monitoring compliance with RWP-related work. In addition, SC&A does not believe instances where the EE submitted a plutonium bioassay during the RWP work necessarily satisfy the RWP-mandated monitoring criteria. SC&A believes the only appropriate time window for submission should be 1 year after the expiration of the RWP.

It should be noted that this finding would not affect the compliance estimates when considering an open window timeframe. Therefore, when strictly evaluating whether EEs who performed radiological work under an RWP were eventually sampled for plutonium and thus their exposures would be included in any subsequent co-exposure model, the compliance estimates reported in RPRT-0102 for open window are a relevant metric. However, it is important to note that a sample taken many years after the exposure may not actually be associated with the original exposure in the formulation of a co-exposure model. When calculating the TWOPOS statistic, the sample would be associated with the year it was taken rather than the year of exposure. If the two years are in different intake periods, for the purposes of calculating a resulting distribution, the meaningful connection between the exposure and sample are lost.

Observation 6: SC&A's objections regarding the acceptable time window for bioassay submission do not affect the RPRT-0102 estimates when considering an open window timeframe. However, SC&A notes that a later monitoring result, as used in a potential co-exposure distribution, is not guaranteed to be reflected in the intake period for which it is intended (i.e., it would be reflected in the year the sample was taken, not the year in which the exposure was incurred).

2.2.5.3 Association of monitored and unmonitored workers on the same RWP

One of the major conclusions of RPRT-0102 is to establish that unmonitored workers were on the same RWP as monitored workers, thus implying the unmonitored exposure would still be represented in any subsequent co-exposure model. Specifically, section 10.0 of RPRT-0102 states:

> for 96.8% of the 2,252 RWPs, at least half of the workers who signed a given RWP were monitored (in the active RWP period or post-RWP window). This implies that it is highly likely that workers who were exposed to plutonium and not monitored had potentially exposed coworkers who were monitored. [ORAUT, 2021, pp. 26–27]

This concept has been discussed previously in similar RWP internal monitoring assessments for SRS under SEC-00103. During that effort, the term "effective monitoring" was coined and referred to the similar situation in which individual RWPs would often contain a mixture of monitored and unmonitored workers. In the case of SRS, an unmonitored worker was considered "effectively monitored" if they were in the same radiological area at the same time and had reasonably similar job responsibilities.

An example of this concept as was applied to SRS can be found in ORAUT-RPRT-0092, section 2.7:

> RWP sample . . . had an unmonitored [subcontractor] on a work crew of four [construction trade workers] in which two prime [EEs] were monitored [and one other subcontractor was monitored], providing a monitoring rate of 75% for the job crew. Both of the [subcontractors] were laborers working on the same task at the same time and for the same duration. For that reason the monitored [subcontractor] could serve as a surrogate for the unmonitored laborer. If the [subcontractors] had not both been laborers working on a common task at the same time, there would be one unmonitored [subcontractor] with no surrogate. [ORAUT, 2019, p. 30]

However, during the SRS review described in the example, the RWPs under evaluation had the level of granularity of actual sign-in work times and job titles. The LANL RWPs contain no such granularity, with no actual sign-in times for work or specific duties performed by the workers who signed the acknowledgement form. Therefore, any assumed connection between the exposure potential for workers based solely on signing the acknowledgement form is questionable. This would be particularly true for RWPs that spanned several months and required different workers to perform several different tasks with individual associated exposure potentials.

Finding 6. The assumed connection between exposure potentials for workers based solely on signing the same RWP acknowledgement form is questionable. This would be particularly true for RWPs that span a significant length of time and require individual workers to perform several different tasks with variable exposure potentials.

2.2.6 Conclusions about RPRT-0102

SC&A's review of RPRT-0102 identified three findings and three observations. SC&A believes additional discussion about the appropriateness of some of the assumptions used by NIOSH in evaluating compliance with RWP-mandated bioassay collection and analysis for plutonium is warranted (findings 4 and 5 and observation 6). SC&A also found questionable the presumption that all workers signing the RWP acknowledgement form had sufficiently similar exposure potential in formulating the effective monitoring statistic (finding 6).

RPRT-0102 postulated that missing bioassay results were largely for justifiable reasons. While SC&A understands there are understandable reasons for mandated bioassays being unfulfilled, it does not share the view that this obviates the importance of those intended analytical monitoring results being unavailable for developing co-exposure models (observation 5).

RPRT-0102 provided examples of RMIs intended to demonstrate the strength of the engineering controls in place to limit potential internal exposures. However, many of these procedural examples post-date the early years of the period evaluated (finding 3, which is discussed in section 2.1.4 as part of the RPRT-0101 review).

Despite these findings and observations, SC&A believes that an appropriate co-exposure model for plutonium may be found acceptable. However, such a determination is a matter of professional judgment for the LANL Work Group and Board as a whole. It is notable that the lowest compliance calculated in RPRT-0102 was for LANL's construction and maintenance contractor (Johnson Controls, with 72 percent plutonium bioassay compliance overall; refer to observation 4).

2.3 Examination of radiological monitoring for exotic radionuclides related to radiological work permits (RPRT-0103)

NIOSH released RPRT-0103 to assess the exposure potential related to RWPs that specified exotic radionuclides. While initially SC&A assumed that this would involve a cross-check of bioassay records against the RWP source terms, NIOSH instead performed an evaluation and characterization of individual RWP records and the institutional controls applied by health physics staff during the performance of the given work task. Specifically, RPRT-0103 states its purpose as follows:

> The ORAU Team notes the LANL Health Physics group only monitored by bioassay those workers thought to have the potential to receive more than 100 mrem [CEDE] per year in the period January 1, 1996, through December 31, 2005. This report examines RWPs for evidence to support the premise that LANL Health Physics performed radiological work in a disciplined manner that minimized inadvertent intakes of radioactive material. [ORAUT, 2022b, p. 7]

SC&A did not identify any observations or findings during its review of these characterizations and generally agrees with NIOSH's characterization of these examples.

SC&A believes this alternate approach was adopted by NIOSH because LANL had indicated that in vitro bioassay was not used to routinely monitor for certain exotic radionuclides. As quoted in section 1.1 of RPRT-0103, LANL Health Physics informed Oak Ridge Associated Universities Team (ORAUT) in 2021 that:

> *During the period January 1, 1996 through December 31, 2005, LANL had no routine bioassay monitoring programs for the following isotopes:*
>
> - *Ac-227*
> - *Cm-244*
> - *Np-237*

- *Pa-231*
- *Sr-90*

> *Routine monitoring programs for these isotopes would only have been established if there was routine work with associated materials likely to result in intakes of 100 mrem committed effective dose or greater. Consequently, no bioassay enrollment criteria for these radionuclides were adopted or promulgated*. [ORAUT, 2022b, pp. 7–8]

If there was no routine monitoring program for these and other non-Pu contaminants, then the performance of a generalized sampling plan to assess bioassay completeness may not be particularly informative. However, since the LANL Work Group had requested an analysis of the completeness and effectiveness of bioassay records, SC&A undertook a characterization of RWPs containing non-Pu radioisotopes to identify any particularly important tasks that likely should have been individually monitored either by in vivo or in vitro methods. SC&A took a graded approach that refined its characterization to focus on the more significant work tasks from an internal dose potential standpoint. The graded approach was completed with the following steps:

1. Characterize available RWPs to identify the primary contaminants and applicable site area.

2. Refine non-Pu RWPs by indications of internal exposure potential and/or internal monitoring (bioassay, nasal swipes, job-specific air monitoring, DAC evaluations, and contamination surveys).

3. Further refine RWPs into those that required non-Pu bioassay and/or had indications of positive measured nasal swipes.

This third grouping was selected for further evaluation of followup in vitro and/or in vivo monitoring to characterize the effectiveness of the LANL individual internal monitoring program in these scenarios (refer to sections 2.3.2, 2.3.3, and 2.3.4 of this report).

2.3.1 Characterization of non-Pu RWP and bioassay monitoring

SC&A was tasked by the LANL Work Group in March 2022 to develop a sampling plan of available RWPs to assess the extent to which workers exposed to exotic radionuclides were appropriately internally monitored consistent with the exotic contaminants of interest identified. To evaluate the feasibility of developing a typical sampling plan, SC&A performed a characterization of each RWP that listed radionuclides other than just plutonium[7] to compile the following information:

- a brief description of the RWP work to be performed
- exotic radionuclides identified

[7] Many RWPs available for analysis contained plutonium in addition to another radionuclide.

- site TA involved
- approximate number of workers[8]
- approximate end date for the work (based on post-job survey, estimated completion of work, or expiration of the RWP)
- prescribed respiratory protection (e.g., full face, supplied air, particulate and/or combination cartridge, and self-contained breathing apparatus)
- air monitoring requirements (e.g., area-specific ventilation, continuous air monitoring, fixed head, portable high-efficiency particulate air, tritium "sniffer," and other job-specific monitoring)
- internal dosimetry requirements (e.g., non-PAL bioassay, nasal smears, and breathing zone/lapel samplers)

Table 15 summarizes RWPs containing non-Pu contaminants (non-Pu RWPs) by year and the approximate number of workers listed on the RWP. Tables 16 and 17 show the total number of non-Pu RWPs by contaminants identified and TA, respectively. As seen in these tables, SC&A identified a total of 767 RWPs that contained radionuclides other than plutonium. The number of workers on a given RWP could range from a single worker to 140 workers signed in on various acknowledgement forms.

Table 15. Summary of RWPs containing non-Pu radionuclides

Year	# of RWPs	Approximate total # of worker-RWP combinations	Min. number of workers per RWP	Average number of workers per RWP	Median number of workers per RWP	Max. number of workers per RWP
1996	82	483	1	6	4	35
1997	142	1,098	1	8	6	33
1998	109	1,033	1	9	6	77
1999	337	3,659	1	13	10	140
2000	36	434	2	13	8	69
2001	32	358	1	11	7	59
2002	25	280	2	11	5	94
2003	0	0	0	0	0	0
2004	6	30	1	5	3	14
2005	2	120	1	60	60	119
Total	767	7,377	NA	NA	NA	NA

[8] The statistics in this section tallying the number of workers may contain duplicate names if workers signed acknowledgement sheets for multiple RWPs or signed multiple acknowledgement sheets for a single RWP.

Table 16. Number of RWPs by non-PU contaminant

Year	U	Am	Np	MFAP	H-3	Th	Other transuranics	Ir-192
1996	38	22	12	24	22	2	0	0
1997	44	78	2	60	15	4	1	0
1998	68	55	4	40	20	8	1	0
1999	59	23	0	253	8	2	1	6
2000	15	10	0	9	10	0	3	2
2001	16	17	0	4	4	0	1	1
2002	2	6	1	3	15	0	0	2
2003	0	0	0	0	0	0	0	0
2004	4	4	1	4	0	0	0	0
2005	2	1	0	1	0	0	0	0
Total	245	216	20	394	94	16	7	11

Note: These totals by year will be different than those found in table 15 because multiple contaminants might appear on the same RWP.

Table 17. Number of non-Pu RWP worker acknowledgement combinations by non-Pu contaminant

Year	U	Am	Np	MFAP	H-3	Th	Other transuranics	Ir-192
1996	207	177	84	190	92	9	0	0
1997	476	757	50	393	62	25	5	0
1998	715	629	17	294	149	38	6	0
1999	515	188	0	2,929	22	6	12	96
2000	119	150	0	121	123	0	30	39
2001	120	177	0	80	24	0	4	37
2002	10	78	5	35	77	0	0	105
2003	0	0	0	0	0	0	0	0
2004	21	27	8	21	0	0	0	0
2005	120	119	0	1	0	0	0	0
Total	2,216	2,302	164	3,946	549	78	57	277

During this initial characterization, SC&A determined that many of these non-Pu RWPs would not be especially useful for further evaluation. Examples of these RWPs might involve the use of sealed sources, RWPs that were never implemented, or other situations in which it is was clear that internal exposure potential (and thus internal monitoring) would likely not be necessary. Therefore, SC&A performed a further reduction in potential RWPs available for further evaluation by only including those that indicated a reasonable potential for internal exposure. SC&A selected RWPs from the full set with one or more of the following internal dose protection requirements:

- respiratory protection
- breathing zone sampling
- nasal smears
- non-PAL bioassay requirements

SC&A did not include RWPs with bioassay requirements only specifying the PAL to avoid duplication of analysis in RPRT-0102 (refer to section 2.2 for a review of RPRT-0102). This

reduced the overall number of RWPs for further consideration from 767 to 348. The characteristics (number of workers, site area, contaminant of interest) of this subset of non-Pu RWPs are described in tables 18–20, respectively. Table 21 shows the number of RWPs that met SC&A's identified internal dose protection requirements for analysis (respiratory protection, breathing zone sampling, nasal smears, and non-PAL bioassay).

Table 18. Summary of workers per RWP with indications of internal exposure potential

Year	# of RWPs	Total # of worker-RWP combinations	Min. number of workers per RWP	Average number of workers per RWP	Median number of workers per RWP	Max. number of workers per RWP
1996	48	289	2	6	4	27
1997	69	593	1	9	7	26
1998	61	559	2	9	7	47
1999	105	1,312	2	12	10	140
2000	19	296	2	16	8	69
2001	19	211	1	11	8	59
2002	23	175	2	8	5	30
2003	0	0	NA	NA	NA	NA
2004	3	20	2	7	4	14
2005	1	119	NA	NA	NA	NA
Total	348	3,574	NA	NA	NA	NA

Table 19. Summary of RWPs with indications of internal exposure monitoring/potential by technical area

Year	TA-3	TA-9	TA-18	TA-21	TA-33	TA-35	TA-48	TA-49	TA-50	TA-53	TA-54	TA-55
1996	24	0	0	15	0	1	0	0	1	0	4	3
1997	20	0	1	3	0	0	0	0	25	0	17	3
1998	17	0	0	0	0	0	6	3	5	0	30	0
1999	35	0	1	0	0	0	1	0	2	61	2	3
2000	6	0	0	0	0	1	0	0	4	1	1	6
2001	12	0	0	1	0	0	0	0	3	0	0	3
2002	2	0	0	14	0	0	0	0	1	1	5	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	3	0	0	0	0	0	0	0	0	0	0	0
2005	1	0	0	0	0	0	0	0	0	0	0	0
Total	120	0	2	33	0	2	7	3	41	63	59	18

Table 20. Summary of RWPs with indications of internal exposure potential by contaminant

Year	U	Am	Np	MFAP	H-3	Th	Other transuranics
1996	21	15	10	8	18	2	0
1997	21	44	1	25	11	3	0
1998	39	30	2	24	17	8	0
1999	29	9	0	89	3	2	0
2000	8	7	0	3	6	0	1
2001	12	9	0	3	3	0	0
2002	2	6	1	3	15	0	0
2003	0	0	0	0	0	0	0
2004	3	2	0	3	0	0	0

Year	U	Am	Np	MFAP	H-3	Th	Other transuranics
2005	1	1	0	0	0	0	0
Total	136	123	14	158	73	15	1

Table 21. Number of RWPs by internal exposure potential

Year	Non-PAL bioassay required	Breathing zone sample required	Nasal swipes required	Respiratory protection required	Total
1996	15	0	28	5	48
1997	3	0	46	20	69
1998	0	12	16	33	61
1999	1	1	80	23	105
2000	1	0	9	9	19
2001	1	0	12	6	19
2002	14	1	3	5	23
2003	0	0	0	0	0
2004	0	0	0	3	3
2005	0	0	0	1	1
Total	35	14	194	105	348

Once this refinement was complete, it was apparent that many of these RWPs (while requiring various levels of direct internal dose monitoring/protection) might not represent contamination incident conditions that might trigger an RWP-specific or incident-based special bioassay. SC&A further characterized the subset of internal exposure potential RWPs to include information such as the pre- and post-job smear surveys and DAC air measurements.[9] These additional metrics were compared against the assumed levels in RPRT-0101, which are representative of the 100 mrem threshold.[10] In addition, RWPs that specified that nasal smears be obtained and for which positive smears were observed were also considered, as discussed in section 2.3.4.

This remaining targeted group of RWPs can be broken down as shown in table 22.

Table 22. Number of RWPs by internal dose potential category (approximate total number of workers signed into RWP)

Year	Urinalysis specified [(a)]	Pre-job DAC [(a)]	Pre-job alpha smear [(a)]	Post-job DAC [(a)]	Post-job alpha smears [(a)]	Positive nasal smears [(a)] [(b)]
1996	15 (72)	0 (0)	3 (22)	0 (0)	4 (20)	0 (0)
1997	3 (7)	0 (0)	1 (2)	0 (0)	3 (17)	6 (67)
1998	0 (0)	1 (15)	3 (55)	0 (0)	2 (32)	2 (21)
1999	1 (10)	0 (0)	4 (44)	0 (0)	4 (20)	6 (50)
2000	1 (3)	0 (0)	1 (4)	1 (69)	1 (7)	1 (7)
2001	1 (8)	0 (0)	0 (0)	0 (0)	0 (0)	2 (22)
2002	14 (69)	0 (0)	1 (3)	0 (0)	0 (0)	0 (0)

[9] It must be noted that SC&A only considered smear and air sampling data in the subset of RWPs that was specified as based on "measurements" and not RWPs where these additional data were "anticipated" or "estimated."

[10] The length of work was not considered, only the relative level of airborne or removable contamination.

Year	Urinalysis specified [a]	Pre-job DAC [a]	Pre-job alpha smear [a]	Post-job DAC [a]	Post-job alpha smears [a]	Positive nasal smears [a] [b]
2003	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
2004	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
2005	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total	35 (169)	1 (15)	13 (130)	1 (69)	14 (96)	17 (167)

[a] The reported totals will differ slightly from those analyzed previously because some workers had illegible names or reported names and employee numbers could not be rectified with the electronic records.

[b] The total number of workers reported in parenthesis does not represent the actual number of positive nasal smears but rather the number of workers signed into the RWP in which at least one nasal smear was positive.

To provide a pilot study that cross-references individual workers with their available internal monitoring records, SC&A evaluated all workers who could be positively identified with a non-PAL urinalysis requirement. Thirty-four RWPs contained a tritium urinalysis requirement, and one RWP was identified that had a uranium and plutonium urinalysis requirement (refer to sections 2.3.2 and 2.3.3, respectively). In addition, SC&A investigated each identifiable worker who submitted a positive nasal smear to assess their internal monitoring (refer to section 2.3.4).

2.3.2 Required tritium urinalysis RWP evaluation

SC&A identified 34 RWPs (covering 147 EEs) that specified that the workers involved must be on a routine tritium bioassay program. SC&A examined the extent to which workers were covered by the routine tritium monitoring program both during and immediately after the end of the job. According to the LANL internal dose TBD (ORAUT, 2013), the sampling protocol for the period of interest was every 2 weeks for routine workers.

Determining the end date of the actual work performed can be difficult to establish. One could simply take the expiration date of the RWP and assume that the work proceeded up until that date. However, this would often overestimate the actual duration of the RWP work (e.g., an RWP is established for glovebox modification that spans a number of months; however, evidence suggests the actual work was completed in a matter of days). In establishing the end date of the RWP work, SC&A used the following hierarchy of evidence, with the earliest date assumed in this analysis:

1. direct evidence via handwritten notes on the RWP for when the work was completed
2. primary survey forms documenting post-job conditions
3. signature date for the post-job conditions checklist in the main RWP form
4. RWP expiration date

Table 23 summarizes by year the RWPs evaluated. As shown in the table, RWPs with tritium-specific bioassay requirements were identified for 1996–1998, 2001, and 2002 (i.e., no tritium requirements on RWPs were available for 1999–2001 or 2003–2005). The range of workers on these identified RWPs who were covered by the tritium bioassay program ranged from ~43 percent in 1998 to 100 percent in 1997 (though these years only had one RWP each). It is noteworthy that one of the highest percentages observed was in the first year of the period of interest (80 percent for 1996), as it is logical to expect that the level of radiological oversight would have likely increased in later years. Over the 4 years with evaluated RWPs, the percentage of workers with complete monitoring coverage was ~73 percent, 23 percent have no evidence of

tritium bioassay coverage for the job,[11] and ~4 percent (6 total workers) were not covered for at least a portion of job.

Table 23. Tritium coverage for RWP-specified tritium urinalysis by year

Year	# RWPs	# Workers	# Monitored completely (%)	# Unmonitored (%)	# Partially monitored (%)
1996	17	70	56 (80.0%)	10 (14.3%)	4 (5.7%)
1997	1	2	2 (100.0%)	0 (0.0%)	0 (0.0%)
1998	1	7	3 (42.9%)	4 (57.1%)	0 (0.0%)
1999–2001	no data	no data	no data	no data	no data
2001	1	6	4 (66.7%)	2 (33.3%)	0 (0.0%)
2002	14	62	42 (67.7%)	9 (14.5%)	2 (3.2%)
2003–2005	no data	no data	no data	no data	no data
Total	**34**	**147**	**107 (72.8%)**	**35 (23.1%)**	**6 (4.1%)**

Those six workers who were classified as "partially covered" by SC&A can generally be described as follows:

1. Last 2 months of the assumed work period are unmonitored (end date of the period based on signature for post-job radiological conditions).
2. Last 3 months of the assumed work period are unmonitored (end date of the period based on signature for post-job radiological conditions).
3. Last month of the assumed work period is unmonitored (end date based on the RWP expiration date) (three workers).
4. Last 5 days of the assumed work period are unmonitored (end date based on a handwritten note indicating when work was expected to end; RWP expiration date is approximately 3 weeks after the last sample).

Therefore, it is not known with certainty whether these workers were appropriately or only partially monitored.

Table 24 shows the breakdown of tritium monitoring by each RWP. In general, most RWPs involved penetrations into gloveboxes for modification, removal, or replacement of other equipment, such as pumps. However, a few other examples included activities related to actual tritium experiments or sampling of tritium materials and wastes.

Notably, SC&A found only 2 of 34 RWPs to be completely unmonitored for tritium (RWP 1 involving one worker and RWP 22 involving seven workers). One RWP involved removal and installation of new ductwork where pre-job contamination surveys indicated levels over 100,000 dpm/cm^2 and airborne concentrations were expected to be greater than 1 DAC (RWP 1 involving a single worker). The other RWP involved the disassembly of electronic instrumentation to separate components from tritium waste. This RWP indicated expected

[11] Three of the 34 workers with no tritium coverage appear to be visitors from other sites, though it is not clear whether they still should have been monitored per the requirements of the RWP (refer to RWPs 13 and 33). Seven of the 34 were on an RWP for which no post-job information exists.

airborne concentration of less than 10 percent of the DAC, and no pre-job smear surveys were taken.

Observation 7. During the period of interest from 1996 to 2005, SC&A identified 34 RWPs covering 147 workers who had tritium bioassay specified. Of these 147 RWP-worker combinations, SC&A found that approximately 73 percent were appropriately monitored throughout the assumed job period, 5 percent were partially monitored, and 22 percent were unmonitored.

Table 24. Tritium coverage by RWP

RWP # [(a)]	# Workers	Year	Brief description of RWP work	Monitored workers (%)	Unmonitored workers (%)	Partially monitored workers (%)	Additional comments
1	[Redacted]	1996	[Redacted]	[Redacted] (0%)	[Redacted] (100%)	[Redacted] (0%)	No airborne activity was measured prior to or after the job; however, the estimated pre-job airborne activity is greater than 1 DAC.
2	[Redacted]	1996	[Redacted]	[Redacted] (60%)	[Redacted] (0%)	[Redacted] (40%)	RWP work end date based on expected end date rather than expiration date, which is 2 weeks after the expected end date.
3	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	End date is based on a post-job survey measurement form. Job requires ventilation and intermittent RCT coverage. Post-job radiological conditions indicate no detectable airborne activity.
4	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Job required a portable duct vent and H-3 removal system. RCT to be notified before each step-in process, though coverage is characterized as intermittent.
5	[Redacted]	1996	[Redacted]	[Redacted] (50%)	[Redacted] (0%)	[Redacted] (50%)	Portable ventilation to be used during window removal. RCT to be notified before each step-in process, though coverage is characterized as intermittent.
6	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Job required continuous RCT coverage and a portable ventilation unit. RWP had to be modified with extra ventilation because a stuck flange required removal of the glovebox window.
7	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Job required continuous RCT coverage and a portable ventilation unit. End date is based on post-job survey measurement form.

RWP # [a]	# Workers	Year	Brief description of RWP work	Monitored workers (%)	Unmonitored workers (%)	Partially monitored workers (%)	Additional comments
8	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Job required continuous RCT coverage and a portable ventilation unit.
9	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Job required intermittent RCT coverage and a portable ventilation unit.
10	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	RWP covers almost the entire year of 1996. Ventilation and continuous RCT coverage required.
11	[Redacted]	1996	[Redacted]	[Redacted] (80%)	[Redacted] (0%)	[Redacted] (20%)	Job required intermittent RCT coverage and portable ventilation unit.
12	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Intermittent coverage by RCT but no ventilation required. End date based on post-job contamination survey form.
13	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	[Redacted]
14	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Job required intermittent RCT coverage and a portable ventilation unit.
15	[Redacted]	1996	[Redacted]	[Redacted] (42%)	[Redacted] (58%)	[Redacted] (0%)	Job required continuous RCT coverage and a portable ventilation unit.
16	[Redacted]	1996	[Redacted]	[Redacted] (75%)	[Redacted] (25%)	[Redacted] (0%)	Job required intermittent RCT coverage and a portable ventilation unit.
17	[Redacted]	1996	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Job required continuous RCT coverage and a portable ventilation unit.

RWP # [(a)]	# Workers	Year	Brief description of RWP work	Monitored workers (%)	Unmonitored workers (%)	Partially monitored workers (%)	Additional comments
18	[Redacted]	1997	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Note on RWP indicates that bioassay kits were issued to all personnel involved. RCT contacted bioassay office and they indicated all involved personnel received a H-3 dose <1 mrem but had not received the hardcopy results.
19	[Redacted]	1998	[Redacted]	[Redacted] (43%)	[Redacted] (57%)	[Redacted] (0%)	This job was covered by a grouping of RWPs that were not clear on the exact end date (i.e., there are several possibilities that are very far apart). Therefore, workers were only designated as uncovered if they had no evidence of tritium monitoring at all. Stop work order is given at air contamination levels 20 µCi/m^3 or surface contamination levels at 50,000 dpm/100 cm^2.
20	[Redacted]	2001	[Redacted]	[Redacted] (67%)	[Redacted] (33%)	[Redacted] (0%)	No ventilation was required, only intermittent RCT coverage. End date is based on post-job contamination survey form. Stop work order is given at air contamination levels 20 µCi/m^3 or surface contamination levels at 50,000 dpm/100 cm^2.
21	[Redacted]	2002	[Redacted]	[Redacted] (67%)	[Redacted] (0%)	[Redacted] (33%)	Ventilation and continuous RCT coverage were specified. End date is based on post-job contamination survey form.

RWP # [(a)]	# Workers	Year	Brief description of RWP work	Monitored workers (%)	Unmonitored workers (%)	Partially monitored workers (%)	Additional comments
22	[Redacted]	2002	[Redacted]	[Redacted] (0%)	[Redacted] (100%)	[Redacted] (0%)	It is handwritten on RWP that special urinalysis should be biweekly. The pre-job conditions only list the estimated value as <10% DAC with no measurements for surface contamination. No post-job information is available; therefore, it is unknown if the job was performed under this RWP.
23	[Redacted]	2002	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Job requires portable ventilation and intermittent coverage. Stop work is set at a breathing zone level of 20 µCi/m^3.
24	[Redacted]	2002	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	End date is based on the expiration date of the RWP. No ventilation was required for this job, but continuous RCT coverage was required. Stop work is set at a breathing zone level of 20 µCi/m^3.
25	[Redacted]	2002	[Redacted]	[Redacted] (80%)	[Redacted] (20%)	[Redacted] (0%)	Exclusion/contamination areas should be established to limit the spread of contamination once the window is removed. Portable ventilation and intermittent coverage are required. Stop work is set at 20 µCi/m^3.
26	[Redacted]	2002	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Portable ventilation and exclusion area (roped off) to control spread of contamination during potential off-gassing operations. Pre-job conditions given as <1 DAC. Portable ventilation and continuous RCT coverage required. Stop work if breathing zone is greater than 20 µCi/m^3 for 5 minutes.

RWP # [(a)]	# Workers	Year	Brief description of RWP work	Monitored workers (%)	Unmonitored workers (%)	Partially monitored workers (%)	Additional comments
27	[Redacted]	2002	[Redacted]	[Redacted] (50%)	[Redacted] (50%)	[Redacted] (0%)	Pre-job conditions given as <1.0 DAC. In general, intermittent RCT coverage is required except during the system breach, when continuous coverage is required. Stop work if breathing zone is greater than 20 µCi/m^3 for 5 minutes.
28	[Redacted]	2002	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Intermittent coverage except when draining the liquids from the system when continuous coverage is required. Portable ventilation and exclusion area (roped off) when draining liquids (and according to contamination levels).
29	[Redacted]	2002	[Redacted]	[Redacted] (67%)	[Redacted] (0%)	[Redacted] (33%)	Estimated pre-job radiological conditions indicates “<10” DAC. Portable ventilation and intermittent coverage required. Stop work if breathing zone is greater than 20 µCi/m^3 for 5 minutes. Roped-off exclusion area to be established based on airborne contamination.
30	[Redacted]	2002	[Redacted]	[Redacted] (80%)	[Redacted] (20%)	[Redacted] (0%)	1 DAC airborne radioactivity expected prior to the job and was also measured in the post-job conditions. RCT coverage set at intermittent. Stop work if airborne contamination is greater than 100 µCi/m^3 for more than 5 minutes.
31	[Redacted]	2002	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	1 DAC airborne radioactivity expected prior to the job and was also measured in the post-job conditions. RCT coverage set at intermittent. Stop work if airborne contamination is greater than 100 µCi/m^3 for more than 5 minutes.

RWP # [a]	# Workers	Year	Brief description of RWP work	Monitored workers (%)	Unmonitored workers (%)	Partially monitored workers (%)	Additional comments
32	[Redacted]	2002	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	1 DAC airborne radioactivity expected prior to the job and was also measured in the post-job conditions. RCT coverage set at intermittent. Stop work if airborne contamination is greater than 100 µCi/m^3 for more than 5 minutes.
33	[Redacted]	2002	[Redacted]	[Redacted] (38%)	[Redacted] (62%)	[Redacted] (0%)	Pre-job radiological conditions expected to be <10 DAC. Ventilation required but RCT coverage is only specified for the start of the job. Stop work point if contamination is greater than 50,000 dpm/100 cm^2 or greater than 20 µCi/m^3. Post-job conditions indicate no measured detectable activity.
34	[Redacted]	2002	[Redacted]	[Redacted] (100%)	[Redacted] (0%)	[Redacted] (0%)	Pre-job radiological conditions expected to be 1 DAC. Ventilation required as well as intermittent RCT coverage. Stop work point if airborne contamination greater than 20 µCi/m^3. Post-job conditions indicate no measured detectable activity.
Total	**[Redacted]**	NA	[Redacted]	**[Redacted] (72.8%)**	**[Redacted] (22.4%)**	**[Redacted] (4.8%)**	NA

[a] RWP numbers are arbitrarily assigned by SC&A and do not represent references to the actual source documents.

2.3.3 Non-tritium special urinalysis RWP evaluation

SC&A only noted a single RWP that required non-tritium special urinalysis as identified in the pre-job work plan. No other reviewed RWPs specified non-tritium urinalysis be performed unless the PAL requirement was also in place. This RWP covered decontamination work where the primary radionuclides identified were plutonium and uranium and included 10 workers who signed the acknowledgement form for the RWP. This RWP required baseline urinalysis, special urinalysis, job-specific air monitoring, and nasal swipes.

Pre-job radiological conditions indicated smear samples to a maximum level of 7,341 dpm/100 cm^2 with other measurements on the floor as high as 3,582 dpm/100 cm^2 (both of which are well above the 400 dpm/100 cm^2 specified in RPRT-0101), though on average the pre-job survey swipes were on the order of 250 dpm/100 cm^2. The measured airborne radioactivity was 0.25 DAC and is associated with Pu-239. Although Pu-239 is not considered an exotic radionuclide at LANL as it was the main product of the laboratory,[12] SC&A believes evaluation of the special urinalysis requirements for this RWP is an important consideration when assessing the bioassay program outside of the PAL system. The standard section of the RWP where post-job radiological conditions in the area are reported was left blank. In addition, several days after the start of the decontamination of the area, the RWP was modified to remove the special urinalysis requirement because air contamination levels had been lowered to an acceptable level after initial decontamination efforts. Therefore, SC&A chose the RWP modification as the assumed end date of the work in evaluating followup bioassay.

SC&A evaluated all 10 workers and their internal dosimetry records to see what followup monitoring for uranium and plutonium may have occurred associated with this work. Although the RWP specifies that special urinalysis be performed, SC&A also evaluated available in vivo records to determine if this radiological work was covered by *any* post-job sampling. Table 25 summarizes SC&A's evaluation of the 10 EEs; each EE's case number is an arbitrarily assigned value by SC&A.

As table 25 indicates, it does not appear that any internal monitoring for uranium occurred post job. The one possible exception was EE Case ID 5, in which there is an [redacted] that thus cannot be tied directly to the RWP. Plutonium was covered by urinalysis in [redacted] of the 10 cases (a fifth case, Case ID 5, had an [redacted]). [Redacted] of the 10 EEs evaluated for this RWP had [redacted] taken during the work. [Redacted] of the 10 EEs had no [redacted] in evidence related to this work.

Observation 8. SC&A identified a single RWP covering 10 workers that specified uranium monitoring in addition to plutonium urinalysis. [Redacted] of the 10 workers did not have [redacted] monitoring identified, [redacted] of 10 only had [redacted] monitoring, and 1 worker had unclear records due to an [redacted].

[12] It should be noted that the pre-job radiological conditions assessment also lists uranium as an expected contaminant.

Table 25. Summary of worker monitoring on RWPs mandating internal monitoring for uranium

EE case ID (a)	Internal monitoring for job covered?	Pu in vivo days post job	Pu in vitro days post job	U in vivo days post job	U in vitro days post job	Nasal smears	Additional comments
1	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	
2	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted] NDA	
3	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]
4	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted] NDA	[Redacted]
5	Unclear	Refer to comment	[Redacted]	Refer to comment	[Redacted]	[Redacted] NDA	[Redacted]
6	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	
7	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted] NDA	[Redacted]
8	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	
9	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	
10	[Redacted]	[Redacted]	Refer to comment	[Redacted]	[Redacted]	[Redacted] NDA	[Redacted]

(a) Each EE's case number is an arbitrarily assigned value by SC&A.

As shown in table 25, only [redacted] of 10 workers had followup monitoring for [redacted] post job (only [redacted] of 10 cases were sampled via urinalysis and [redacted] of these three was well over [redacted] post job). There was no evidence of followup monitoring for uranium; although in one case a [redacted] was found, it was undated and so could not be correlated with the RWP dates of work. Of the [redacted] workers who signed the RWP and did not clearly have followup monitoring, [redacted] had some form of [redacted] taken during the RWP work; all results had no detectable activity (NDA).

2.3.4 Evaluation of bioassay followup to positive nasal swipes

As noted in section 2.3.1, there was a significant number of RWPs in which nasal swipes were required to be taken during the job. The RWPs reviewed did not specify at what intervals or under what conditions the nasal swipes should be taken, so SC&A assumes this was at the discretion of the RCT responsible for oversight. The results of the vast majority of observed nasal swabs taken indicated no detectable activity; however, SC&A identified 24 positive nasal smears to evaluate for any internal monitoring followup.

Similar to the previous analyses (section 2.3.1), the focus of this evaluation is on RWPs that included contaminants other than just plutonium and were not part of the PAL system. As table 26 shows, there were 7 incidents of nasal contamination involving MFPs, 4 involving uranium, and 17 involving americium.

Table 26. Summary of internal monitoring coverage of non-PAL nasal contaminations

Radionuclide category	# Non-PAL nasal contamination incidents	# Monitored via in vivo (%)	# Monitored via in vitro (%)	# Nasal contamination incidents covered (%)
MFAP	7 [(a)]	4 (57%)	0 (0%)	4 (57%) [(a)]
Uranium	4	0 (0%) [(b)]	0 (0%)	0 (0%) [(b)]
Americium	17	11 (65%) [(c)]	2 (12%)	13 (76%)
All non-Pu contaminants	24	Not applicable	Not applicable	14 (58%)

(a) Note that one of the seven entries had a handwritten note that the positive nasal smear may have been in error (refer to entry 30 in table 27).

(b) Two of the four cases of uranium nasal contamination had evidence of uranium chest counts in their records; however, they are undated and therefore cannot be directly connected to the incident.

(c) Two of the 17 cases of americium nasal contamination had evidence of americium chest counts in their records, but they are undated and therefore cannot be directly connected to the incident. However, these two instances were covered by in vitro monitoring for americium.

As described in the notes to table 26, there were five cases in which a direct comparison of the nasal contamination incident to subsequent internal monitoring was questionable. In four of the five cases, internal monitoring did exist in the form of chest counts; however, because these chest counts were undated, it is not certain when they occurred in relation to the actual contamination incident. For two of these (the americium incidents), there was followup in vitro monitoring, which renders the issue moot when assessing the overall internal monitoring coverage. However, the two uranium incidents remain unresolved. In addition to the four undated chest counts, one incident of a positive nasal swipe had a handwritten note that indicated the result was invalid. However, SC&A could find no actual documentation of the followup measurements showing the result should have been NDA. If this sample is assumed to be

invalidated and the uranium chest counts are assumed to be related to the nasal swipe incidents, the number of nasal contaminations covered by internal dosimetry increases from 14 to 17 (58 percent to 71 percent). Table 27 gives further details about each of the 24 nasal contamination incidents.

Observation 9. SC&A identified 24 individuals with positive nasal contaminations and evaluated their internal monitoring records. The number of individuals with followup monitoring varied from 14 to 17 (58 percent to 71 percent) depending on certain assumptions about undated records and potentially invalid positive nasal swipes.

Table 27. Followup bioassay evaluation for individuals with positive nasal swipes

EE # with positive smear [(a)]	Brief RWP description	Radionuclides identified in RWP	Year of positive nasal smear	Job covered by in vivo?	Job covered by in vitro?	Job covered	Comment
11	[Redacted]	[Redacted]	1999	No	No	No	[Redacted]
12	[Redacted]	[Redacted]	1999	No	No	No	[Redacted]
13	[Redacted]	[Redacted]	1999	Yes	No	Yes	[Redacted]

EE # with positive smear [(a)]	Brief RWP description	Radionuclides identified in RWP	Year of positive nasal smear	Job covered by in vivo?	Job covered by in vitro?	Job covered	Comment
14	[Redacted]	[Redacted]	1999	Yes	No	Yes	[Redacted]
15	[Redacted]	[Redacted]	1999	Yes	No	Yes	[Redacted]
16	[Redacted]	[Redacted]	1999	Yes	No	Yes	[Redacted]

EE # with positive smear [(a)]	Brief RWP description	Radionuclides identified in RWP	Year of positive nasal smear	Job covered by in vivo?	Job covered by in vitro?	Job covered	Comment
17	[Redacted]	[Redacted]	1997	Yes	Pu only	Yes	[Redacted]
18	[Redacted]	[Redacted]	1997	No	No	No	[Redacted]
19	[Redacted]	[Redacted]	1997	No	No	No	[Redacted]
20	[Redacted]	[Redacted]	1997	Yes	Pu only	Yes	[Redacted]

EE # with positive smear [(a)]	Brief RWP description	Radionuclides identified in RWP	Year of positive nasal smear	Job covered by in vivo?	Job covered by in vitro?	Job covered	Comment
21	[Redacted]	[Redacted]	1997	No	Pu only	No	[Redacted]
22	[Redacted]	[Redacted]	1997	Yes	Pu only	Yes	[Redacted]
23	[Redacted]	[Redacted]	1997	Yes	Pu only	Yes	[Redacted]
24	[Redacted]	[Redacted]	1997	Yes	Pu only	Yes	[Redacted]

EE # with positive smear [(a)]	Brief RWP description	Radionuclides identified in RWP	Year of positive nasal smear	Job covered by in vivo?	Job covered by in vitro?	Job covered	Comment
25	[Redacted]	[Redacted]	1997	Yes	Pu only	Yes	[Redacted]
26	[Redacted]	[Redacted]	1997	Yes	Pu only	Yes	[Redacted]
27	[Redacted]	[Redacted]	1997	Yes	Pu only	Yes	[Redacted]
28	[Redacted]	[Redacted]	2001	Yes	Pu only	Yes	[Redacted]

EE # with positive smear [(a)]	Brief RWP description	Radionuclides identified in RWP	Year of positive nasal smear	Job covered by in vivo?	Job covered by in vitro?	Job covered	Comment
29	[Redacted]	[Redacted]	2001	Yes	Pu only	Yes	[Redacted]
30	[Redacted]	[Redacted]	1998	No	Pu only	No	[Redacted]
31	[Redacted]	[Redacted]	1997	Unknown	Pu/Am only	Unknown	[Redacted]
32	[Redacted]	[Redacted]	2000	Unknown	Pu/Am only	Unknown	[Redacted]

EE # with positive smear [(a)]	Brief RWP description	Radionuclides identified in RWP	Year of positive nasal smear	Job covered by in vivo?	Job covered by in vitro?	Job covered	Comment
33	[Redacted]	[Redacted]	2001	No	Pu only	No	[Redacted]
34	[Redacted]	[Redacted]	1997	Pu/Am only	Pu only	No	[Redacted]

(a) EE = Energy employee with an arbitrary number assigned by SC&A that does not reflect personally identifiable information.
[Redacted]

2.3.5 SC&A conclusions about bioassay coverage for non-Pu contaminants

LANL health physics personnel have indicated that there was no routine monitoring program for exotic radionuclides; however, the pertinent issue is adequate monitoring for nonroutine situations. SC&A undertook a characterization of RWPs to identify any such situations in which some form of direct internal monitoring may have been appropriate (e.g., actual bioassay requirements, nasal swipes, required air monitoring, or measured contamination levels). SC&A further refined this grouping of RWPs into those that specifically had a non-Pu bioassay requirement and/or had evidence of positive nasal swipes. SC&A chose these two groups to review in vitro and in vivo monitoring associated with the RWP.

SC&A's evaluation of RWPs requiring tritium bioassay found that 73 percent were completely covered by the bioassay program, 4 percent were partially covered, and 23 percent were not monitored in association with the RWP work task (observation 7). SC&A only identified a single RWP that specified non-tritium/non-plutonium monitoring (uranium monitoring was required). Of the 10 workers associated with this RWP, 50 percent had no internal monitoring identified, 40 percent only had plutonium monitoring, and the 10th worker's status was indeterminate (observation 8).

Finally, analysis of 24 workers who had positive nasal swipes and that were associated with non-Pu contaminants found that 58–71 percent had appropriate followup internal monitoring. The higher figure (71 percent) assumes that undated internal monitoring was actually associated with the contaminated nasal swipe and that one identified nasal swipe was invalidated due to an electrical storm. The lower figure (58 percent) does not count these assumptions as valid monitoring of the nasal contamination (observation 9).

3 Overall Programmatic Considerations for Internal Dosimetry at LANL

In addition to SC&A's specific findings and observations about each of the three main NIOSH reports under consideration, further discussion of the programmatic concerns raised throughout the SEC period under evaluation is warranted. The work group has been engaged with NIOSH on questions of bioassay data sufficiency for the SEC-00106 ER since 2009 and has addressed a succession of approaches advanced by NIOSH through which LANL internal doses, particularly for exotics, could be reconstructed with sufficient accuracy. The following subsections provide an additional discussion of sitewide programmatic concerns that ties that review history with current questions of data and program adequacy.

3.1 Programmatic history and issues

Section 1.2 of this report gives a detailed chronology of the proceedings of the LANL Work Group on programmatic issues surrounding the SEC-00109 ER (2009, revised 2012) and its subsequent Addendum (2017). The following review confines itself to the implications of the recently issued RPRT-0101, RPRT-0102, and RPRT-0103 for those program issues and positions.

As outlined by presentations and discussions at the July 25, 2019, work group meeting (ABRWH, 2019, pp. 9–11, 18–19; NIOSH, 2019b, slides 5–11), NIOSH and the work group agreed on a two-fold assessment for LANL to resolve issues raised over the SEC-00106 Addendum:

1. Responding to remaining questions about the dose reconstructability of mixed activation and fission products ("exotics"), NIOSH was to conduct a review of surface contamination and airborne radioactivity concentration surveys to confirm whether any exceeded the proposed 100 mrem/year CEDE bounding dose. RPRT-0101, supplemented by RPRT-0103's sampling of 24 RWPs and attendant radiological program controls, were intended to address this question for the 1996–2005 timeframe.

2. Responding to work group concerns raised by NC ID 484, NIOSH was to conduct a sampling survey of available RWPs, similar to what was performed at SRS, to determine conformance with bioassay requirements (or, as recommended by SC&A: "to ascertain whether the bioassay incompleteness identified in the limited sampling in 1999 reflects a broader incompleteness in LANL's bioassay database for 1996–2000" (SC&A, 2019, p. 10)). As noted in section 1.2 of this report, NIOSH eventually dropped a sampling approach in favor of using all available routine bioassay results. RPRT-0102 addresses the basis for applying a co-exposure model for routine plutonium bioassays.

Following issuance of RPRT-0101 and 0102, the work group tasked SC&A with review of those reports and, in parallel, to review available RWPs, captured by NIOSH, as a further means to assess job-specific bioassay data completeness, particularly for source terms other than plutonium and other primary radionuclides (ABRWH, 2022). Prior to SC&A's response to this additional tasking, contained herein, NIOSH developed and released RPRT-0103, which offered

its own sampling of 24 RWPs to compare the programmatic controls afforded exotics with those for the primary radionuclides.

3.2 RPRT-0101 and RPRT-0103 program considerations

The review described in this section expands upon SC&A's evaluation of the radiological control program in section 2.1.4 of this report, as a means to further assess how the LANL radiological control program was "designed" and implemented to comply with the requirements of 10 CFR Part 835 (ORAUT, 2022a, p. 7), notably 10 CFR 835.402 for personnel monitoring, and to what extent actual evidence is available to confirm that the program was, in fact, functioning as intended by site procedures.

3.2.1 Scope of coverage

In section 2.0 of RPRT-0101, NIOSH describes the LANL radiological control program in terms of the potential contamination areas defined, incorporation of engineering control procedures, depth and scope of workplace monitoring procedures and instructions, worker self-monitoring procedures, and the onsite capability for portal monitoring (with examples of recorded incidents where portal monitors were alarmed due to worker contamination). These procedural descriptions and examples are intended to support NIOSH's conclusion that "LANL Health Physics operated a comprehensive radiological control program through the entirety of the evaluated period, 1996 through 2005" (ORAUT, 2022a, p. 8).

However, as already noted in finding 3 (section 2.1.4), NIOSH's RMI examples intended to demonstrate contamination surveying and air monitoring responsibilities were dated as taking effect in the year 2000 or later (except for the one for TA-48, which was effective July 1997). Additionally, examples of incidents in 1996 with fixed monitoring stations used to control contamination at location entrances were for TA-55, which is the plutonium facility and may not be representative of the facilities where exotics were handled.

To expand the scope of the LANL radiological control program review to better encompass the facilities and years in question (1996–2005), SC&A reviewed all available program oversight assessments, including internal laboratory reviews, DOE oversight assessments, and DOE enforcement actions for 1996–2005, as well as available ORPS incident reports.[13] This was intended to move beyond LANL internal dosimetry program descriptions and procedures and to examine the program's actual record of performance based on independent assessments. Section 3.5 discusses two such assessments that followed program upgrades implemented after the 1999 LANL self-assessment that led to NC ID 484.

NIOSH emphasized the distinction between the exposure conditions and controls for the primary radionuclides and exotics, respectively, as part of its basis for supporting an SEC class for 1976–1995, as noted in commentary before the LANL Work Group:

[13] SC&A reviewed LANL entries for the period 1996–2005 in DOE's NTS, the ORPS system, the Nuclear Material Management and Safeguards System, and available LANL and DOE assessments. (Note that SC&A requested two key LANL internal dosimetry program self-assessments for this time period, but apparently they had been destroyed under LANL's records retention policy.)

> But one of the main reasons we think [for recommending an SEC class be defined] is that [given] **the exposure to these exotics we could not demonstrate with any degree of confidence that the exposures were controlled and handled in a similar manner** [to those of the primary radionuclides, including plutonium].
>
> Even though the health physics program seemed to be in place, it seems that **these exotics which were not used on a routine basis** would have been -- could have had different types of exposure conditions present than what you would experience with the things like plutonium and uranium.
>
> So in other words, the exposure to the exotics, you know, might -- were on a much more intermittent experimental basis or very much episodic in nature that would preclude the use of this chronic exposure model that was developed for things like plutonium and uranium.
>
> And in addition, the short duration exposures that were established for these small experiments might not have had similar engineering controls. We just couldn't determine that to any degree of -- with any degree of confidence.
>
> So after reviewing all of that information we agree or we decided that we would — [an SEC] Class should be added based on our inability to reconstruct doses for these exotics and mixed fission activation products from January 1st, '76, all the way through the end of December, '95. [ABRWH, 2012c, pp. 10–11; emphasis added]

As already noted in section 2.1.1, RPRT-0101 (p. 7) defines its scope with an emphasis on "workers doing routine work, such as guards and custodians." Because such work is "defined as work not done under a radiation work permit (RWP)" (p. 7), nonroutine exposures that characterize the intermittent nature of much exotic handling at LANL would seemingly not be included. Observation 1 of this report notes that a clear specification of the worker job types and radionuclides covered by the 100 mrem approach is warranted to clearly distinguish between the RPRT-0101 approach and any future development of co-exposure models for unmonitored workers who should have been monitored or whose records are unavailable. SC&A, the work group, and NIOSH (at least in 2012), have long accepted that internal intakes of exotic radionuclides at LANL had been historically on an intermittent, nonroutine basis, involving episodic releases or contaminations from operations. During the current period under evaluation, it has not been demonstrated that bioassay monitoring results are sufficient to construct a co-exposure model for other than possibly plutonium and the other primaries, nor has it been suggested that NIOSH intends to evaluate the potential for such a model for exotics, with the possible exception of TA-53 (LANSCE) where that possibility is being explored.

3.2.2 Programmatic basis for 100 mrem bounding dose for exotics

As SC&A asked in its July 2017 memorandum, "If, as stated for the NIOSH recommendation for the SEC class for 1972–1995, that inadequate air sampling data existed for exotics, MAPs, and MFPs to support dose reconstruction, how is that different after 1995?" (SC&A, 2017a, p. 13). At that time, SC&A concluded that "there is no evidence that the internal dosimetry and

monitoring shortfalls cited in deliberations that led to the recommendation by the Advisory Board to define an SEC class for 1976–1995 . . . have been resolved for the time period after 1995" (SC&A, 2017a, p. 13).

In response, NIOSH first adopted a position that presumed LANL compliance with the 10 CFR Part 835 monitoring threshold of 100 mrem CEDE per year, providing a basis for an upper bound for internal dose for unmonitored workers. Given evidence of substantial noncompliance with this and other 10 CFR Part 835 bioassay monitoring requirements, as documented in NC ID 484, NIOSH now accepts that compliance alone was not "sufficient" for demonstrating monitoring program adequacy (NIOSH, 2018a, p. 6). Based on its review of LANL's field monitoring programs as provided in NIOSH's ER Addendum, section 6.1.1, however, NIOSH continues to conclude that by the same effective date of 10 CFR Part 835 implementation (January 1, 1996), "The field monitoring and contamination control programs at LANL were well-established and formalized" (NIOSH, 2018a, p. 30), and, accordingly, in terms of monitoring, were "designed and implemented for the purpose of ensuring that unmonitored individuals were unlikely to receive annual intakes of 100 mrem CEDE" (NIOSH, 2018a, p. 9). Finally, NIOSH observed that "Although 10 CFR 835 contains a lot of nuances and implementation guides that may have come out too late to impact RPP [radiation protection program] development by January 1, 1996, the important question is not overall implementation and compliance with 100 percent of 10 CFR 835, but rather, **whether there was a program in place ensuring that unmonitored workers were unlikely to receive intakes resulting in 100 mrem CEDE**" (NIOSH, 2018a, pp. 6–7; emphasis added).

NIOSH considers "use of exotic radionuclides at LANL was relatively rare," and based on interviews with LANL health physics staff, that internal dosimetry was performed only on an "as-needed basis" and that bioassay monitoring was only required for "radiological workers likely to receive 100 mrem annually from internal exposure" (NIOSH, 2018a, pp. 12–13). NIOSH notes that "NIOSH has not found any evidence suggesting that the case would be otherwise for unmonitored workers, or that intakes of exotic radionuclides would have been higher" (NIOSH, 2018a, p. 6).

SC&A acknowledges that "releases of, and occupational exposures to, airborne radionuclides, including exotics, had declined at LANL by the mid-1990s" (SC&A, 2018a, p. 11). However, as noted in section 3.3 of this report, exotic radionuclides continued to be substantially handled and processed at LANL after 1995. They still constituted regular airborne emissions at LANSCE (TA-53), continued to figure in isotope production and experimentation, and were present in legacy contamination at CMR and TA-48. And as DOE emphasized in its programmatic assessment of the internal dosimetry program at LANL in 2001,

> it is recognized that low-level, chronic, or intermittent occupational exposures to radioactive materials may be difficult to avoid due to the types of material handled/processed, their chemical/physical forms, and the nature of the operation, and that incidents may cause unplanned releases of radioactive material. [DOE, 2001, PDF p. 8]

As shown by NIOSH's own survey of air sampling data in RPRT-0101, the highest percentages of observed results for potential worker exposures due to exotics that were above the 100 mrem

limit were for TA-53 during 1996 and 1997 (~33 percent and 22 percent, respectively) (refer to observation 3 of this report, section 2.1.3.2).

SC&A does not share NIOSH's apparent support of LANL's contention that bioassay data are scarce for exotic radionuclides because "workers were not required to have been monitored for them" (NIOSH, 2018a, p. 22). As noted in previous work group meetings and reports, LANL responses, and DOE oversight reviews,[14] LANL's bioassay program had been found to lack adequate monitoring for potential exposures to exotic radionuclides, a circumstance that predated 10 CFR Part 835 and its 1996 implementation date. It is also understood that LANL's approach for bioassay determinations also relies on engineering controls, personal protective equipment, and respiratory protection, backed up by RWP-driven surveillance of job contamination levels, to trigger an assessment for the need for bioassay. However, NIOSH's program descriptions and procedural highlights in RPRT-0101 and RPRT-0103 do not substantiate whether and when program changes would have made a difference after 1995.

In a January 2000 revision of "Internal Dosimetry and Bioassay Requirements for LANL Operations," LANL identified 24 secondary radionuclides, including exotics,[15] which could be encountered in LANL operations (LANL, 2000a). Identified for each were minimum detectable dose equivalents for designated counting intervals and recommended in vivo counting intervals to ensure that a "positive result [was obtained] 95% of the time from an intake corresponding to a committed effective dose equivalent of 100 mrem" (LANL, 2000a, PDF p. 40). Relevant to this listing, the 1999 LANL self-assessment observed that "internal doses from short-lived emitters at LANCE may not be accurately assessed" because the semiannual in vivo counts performed "are not adequate" (Bracket & La Bone, 1999, PDF p. 10), e.g., not frequent enough to satisfy the 100 mrem monitoring requirement for some of the 24 secondary radionuclides listed in table 1 of LANL (2000a).[16] A formal, systematic means to gauge monitoring requirements for short-lived MAPs in terms of meeting the 100 mrem CEDE was not defined and issued as a LANL requirement until this July 1999 laboratory-wide requirement.

As posited by SC&A in 2018, reflecting on the history of various approaches to bound exotic radionuclides at LANL (SC&A, 2018a, p. 12):

> On what is the assumed 100 mrem CEDE bounding dose for exotic radionuclides to be based if the following are true: (1) the compliance basis of 10 CFR Part 835 is no longer a sufficient basis for benchmarking 100 mrem CEDE, (2) the use of primary radionuclide bioassay results to bound or compare those of exotic radionuclides is inappropriate, (3) bioassay data are found to be likely incomplete

[14] For example, ABRWH (2012b), pp. 241–246; ABRWH (2012c), pp. 7–11; NIOSH (2012a), slide 10; LANL (2013), pp. 2–3; and DOE (2001), PDF pp. 8–9.

[15] Beryllium-7, sodium (Na)-22, scandium-46, vanadium (V)-48, chromium-51, manganese (Mn)-59, cobalt (Co)-56, Co-58, Co-60, zinc-65, copper-67, selenium-75, zirconium-95, antimony-124, cesium (Cs)-134, Cs-137, cerium-141, neodymium (Nd)-147, europium-152, osmium-185, thallium (Tl)-201, Tl-202, and mercury-203 (LANL, 2000a, table 1, PDF p. 41).

[16] For example, as an extreme example, Nd-147, with a minimum detectable level of 3,000 mrem CEDE, would require an in vivo counting interval of 14 days, with Tl-202 (370 mrem) needing an interval of 60 days, and Co-56 (200 mrem) requiring 90 days (LANL, 1999, PDF p. 41).

> and program implementation inadequate from the 1999 LANL self-assessment, and (4) bioassay data for exotic radionuclides remain unavailable, as acknowledged in the ER [NIOSH, 2017a] and NIOSH white paper [NIOSH, 2018a]?

What has been lacking is a dose assessment for routine and nonroutine exotic radionuclide exposure that shows occupational doses would be below the threshold of 100 mrem CEDE per year by 1996. The RPRT-0101 survey of three LANL facilities provides a limited sampling of potential exposure source terms for three facilities handling exotics but does not necessarily demonstrate that LANL adequately characterized the potential for nonroutine exposures to exotics and reflected those exposures likely to exceed 100 mrem/year in its RWP bioassay requirements.

SC&A's specific responses to NIOSH's "weight of evidence" programmatic positions in RPRT-0101 (ORAUT, 2022a, p. 27) and "preponderance of evidence" in RPRT-0102 (ORAUT, 2021, p. 7), are addressed in the following sections.

3.3 Nonroutine bioassay monitoring of exotic radionuclides

As noted by NIOSH in its "NIOSH Response to NTS Report NC ID 484 (LANL)":

> All three of these deficiencies [regarding ineffective health physics checklists, lack of participation in RWP-required bioassay programs, and inadequate bioassay enrollment of subcontractor workers] are in regard to workers not fully participating in the appropriate routine bioassay programs. Given the lack of available bioassay data for exotic radionuclides, it appears that there were no "routine" bioassay programs in place for "exotic" radionuclides at the time of the 1999 self-assessment. This suggests that the deficiencies identified were all concerns with the routine bioassay programs for the primary radionuclides handled at LANL (i.e., americium, uranium, plutonium, tritium, and Cs-137). [NIOSH 2019a, p. 21]

On that basis, as observed in RPRT-0102, NIOSH concludes that compliance-based shortcomings would have no impact on performing a DR or developing a co-exposure model for plutonium intakes (ORAUT, 2021, p. 10). However, as SC&A emphasized in its 2019 response (SC&A, 2019), while NC ID 484 did reference routine bioassay programs for plutonium, the identified deficiencies (e.g., missing RWP-directed, job-specific bioassays) directly impact the adequacy and completeness of bioassays for other exposure sources at LANL, notably for exotics, including MAPs and MFPs.

RPRT-0101 indicates that its sampling surveys for exotics at three LANL facilities (TA-3, TA-48, and TA-53) show that "LANL controlled **routine** contamination that could lead to doses greater than 100 mrem at all three TAs" (ORAUT, 2022a, p. 27; emphasis added).

For **nonroutine** exposure to exotics, as addressed in RPRT-0103, ORAUT reviewed 24 RWPs from the same facilities over the 1996–2005 time period. As observed by NIOSH, "No bioassay enrollment criteria for these radionuclides were adopted or promulgated, but LANL had the

capacity to perform bioassay for these radionuclides if warranted [Hoover, 2008, 2021]" (ORAUT, 2022b, p. 10).

This latter position is essentially the same as the one in the NIOSH SEC-00109 (revision 1) ER for the SEC period 1976–1995: "LANL clearly possessed capabilities to conduct bioassay measurements for these exotic radionuclides ([Hoover] 2008); however, specific data for such measurements are very sparse and generally unavailable" (NIOSH, 2012b, p. 42). The LANL Work Group and NIOSH agreed that NIOSH's approach, at the time, to remedy the lack of bioassay data for exotics using bioassays for surrogate primary radionuclides would not enable DR with sufficient accuracy.[17] As SC&A has noted as early as 2010 (SC&A, 2010, p. 14), technological capability or capacity to monitor exotic exposures does not necessarily equate to implementation of an adequate bioassay monitoring program. For its current position on bioassay data availability for exotics, NIOSH cites LANL's position that internal dosimetry would have been performed only on an "as-needed basis" and that internal dosimetry "monitoring is only required for radiological workers likely to receive 100 mrem annually from internal exposure" (NIOSH, 2018a, pp. 12–13).

While SC&A agrees with NIOSH that handling and production of exotic radionuclides has always been relatively rare at LANL compared with the primaries (e.g., plutonium, uranium, tritium, americium), the work group and NIOSH had agreed that for 1976–1995, they were significant enough from an exposure standpoint to warrant dose reconstructability consideration for that SEC evaluation, quite apart from the scarcity of bioassay data and LANL's stated policy (i.e., monitoring as needed).[18] While sources of exotics diminished somewhat in the succeeding years 1996–2005 due to changes in operations and improving emissions controls at LANSCE, the exposure potential that remained is evident in the operations, contamination, and emissions reporting for facilities such as CMR, TA-48, and LANSCE.

The CMR facility was heavily involved in research and development and waste processing to support the weapons program, with mixed fission and activation products (including technetium-99, Cs-137, and Na-22) being present as legacy contamination and in waste processing streams. Accelerator facilities, such as LANSCE, continued to be used to produce both stable and radioactive elements for use by the DOE complex and commercial vendors, with airborne emissions of short-lived MAPs contributing to onsite and offsite exposures. The Radiochemistry site (including TA-48) encompassed hot cells and laboratories where drill back cores from Nevada Test Site had been processed and for which legacy MFP contamination remained a concern. The isotope production programs involved a spectrum of exotic radionuclides and included bench scale experimentation and handling. Legacy or "source unknown" contaminations involving exotic radionuclides are cited regularly in ORPS incident

[17] Exemplified by work group discussions for May 14, 2012 (ABRWH, 2012b), and September 11, 2012 (ABRWH, 2012c, pp. 8–12).

[18] The LANL policy and the 100 mrem/year monitoring threshold requirement had been proceduralized well before 10 CFR Part 835 implementation due to the issuance of DOE Order 5480.11 in 1989.

reports during 1996–2005 for LANL facilities such as CMR and the Radiochemistry site (TA-48).[19]

LANL's program posture and practices remained the same from the SEC designated period of 1976–1995 through the early part of the ER period under current review: Its bioassay monitoring was focused on the primary radionuclides, with exotics addressed only on an as-needed basis. The salient question, therefore, becomes whether the tenet of applying the 100 mrem/year CEDE threshold required by 10 CFR Part 835 (and DOE Order 5480.11 before it) was, in fact, adequately implemented across the site, including updated facility and operations exposure reviews, bioassay enrollments, and RWP-directed job-specific bioassays for exotic radionuclides and activities involving nonroutine exposure potential. In this instance, unlike the co-exposure model feasibility for routine plutonium bioassay program discussed in RPRT-0102, the ability to demonstrate that the required 100 mrem/year monitoring threshold was applied adequately sitewide—for exotic radionuclides and for nonroutine as well as routine work—is fundamental to satisfying the tenets of data completeness and representativeness under 42 CFR 83.14 and DCAS-IG-006. Again, NIOSH's admonition that "the important question is not overall implementation and compliance with 100 percent of 10 CFR 835, but rather, **whether there was a program in place ensuring that unmonitored workers were unlikely to receive intakes resulting in 100 mrem CEDE**" (NIOSH, 2018a, pp. 6–7; emphasis added) applies here.

In summary, the 100 mrem/year threshold is bounding of LANL internal exposures for exotic radionuclide exposure sources if (1) it can be demonstrated that nonroutine, RWP-driven, job-specific bioassays are sufficiently complete (and representative) for operational exposure sources, and (2) that LANL programs to ensure that bioassay enrollments and job-specific bioassay requirements applying that monitoring threshold were adequately implemented. SC&A finds that the sampling reviews and program evaluations in RPRT-0101 and RPRT-0103 do not provide these demonstrations for exotic radionuclide exposure sources.

Finding 7. SC&A finds that RPRT-0101 and RPRT-0103 do not demonstrate that nonroutine job-specific bioassays were adequately evaluated for potential operational exposures to exotics, and that LANL monitoring programs were being adequately implemented to ensure that unmonitored workers were unlikely to receive intakes resulting in 100 mrem CEDE.

3.4 Regulatory compliance versus co-exposure modeling

In RPRT-0102, section 4.0, "Regulatory Compliance versus Co-Exposure Modeling," ORAUT concludes that "compliance with the regulations in place at the time the radiological work was performed is not required in order to perform a dose reconstruction or develop a co-exposure model" (ORAUT, 2021, p. 10). SC&A does not and has never disagreed with this position.

The question of compliance in the context of LANL SEC-00109 DR feasibility was originally advanced by NIOSH in its use of a proposed "presumption of compliance" related to

[19] For example, refer to ORPS reports DP-ALO-LA-LANL-CMR-1998-0033, DP-ALO-LA-LANL-CMR-1999-0011, DP-ALO-LA-LANL-CMR-1999-0030, DP-ALO-LA-LANL-CMR-2000-0003, DP-ALO-LA-LANL-CMR-2002-0002, DP-ALO-LA-LANL-RADIOCHEM-1997-0001, DP-ALO-LA-LANL-RADIOCHEM-1997-0003, DP-ALO-LA-RADIOCHEM-1996-0005, and DP-ALO-LA-LANL-RADIOCHEM-1997-0005.

implementation of 10 CFR Part 835 regulations for LANL on January 1, 1996 (NIOSH, 2017a, p. 17). That presumption was based on the rule's provision at 10 CFR 835.402(c)(1) that internal dosimetry programs shall be conducted "for radiological workers who, under typical conditions, are likely to receive a committed effective dose equivalent of [100 mrem] or more from all occupational radionuclide intakes in a year." In effect, NIOSH's presumption of compliance derived from an enforcement milestone beginning in 1996, at which time it would have been assumed that LANL monitored all workers with a likelihood of receiving 100 mrem of internal exposure in a year and maintained corresponding records (SC&A, 2017a).

SC&A disagreed with the presumption-of-compliance proposal and argued that presumed compliance should not be equated to program implementation or bioassay data completeness. The following discussion, excerpted from SC&A's 2017 review, remains relevant and addresses the issue raised by NIOSH in section 4.0 of RPRT-0102 (SC&A, 2017a, p. 3):

> First, the use of a presumption of compliance can be taken to infer that regulatory compliance equates to program implementation. Program compliance with 10 CFR Part 835, while necessary under DOE's Price-Anderson regulatory framework, is not sufficient for demonstrating that actual radiation program practice is adequate. . . . While the DOE rule or its antecedent, DOE Order 5480.11, *Radiation Protection for Occupational Workers* (DOE, 1988), had requirements that were to be translated into contractor procedures, in the end, the real question is whether those procedures appropriately interpreted the requirements and were carried out by all concerned. External regulatory oversight is typically a blunt instrument for identifying what are often imbedded culture-based workplace safety program gaps and deficiencies.
>
> Second, while the Price Anderson program for 10 CFR Part 835 entailed a clearly defined review and approval process and enactment date, the actual upgrades to DOE's site-specific radiological control programs were more evolutionary in nature and paced successive Departmental policy developments. As noted in the ER Addendum, the 100 mrem committed effective dose equivalent (CEDE) criterion for individual monitoring was first defined for DOE-wide application by DOE Order 5480.11 in 1989. These provisions were, in turn, referenced by the Tiger Team compliance assessments in 1989–1990. They were adopted in guidelines applied across the Department through the Radiological Control Manual beginning in 1992.

As stressed by the DOE headquarters lead manager for 10 CFR Part 835 program implementation in the 1990s:

> Overall it seems as though the basic elements of [the] current dosimetry system have been [in] place since 1989. Accordingly, 1/1/1996 may not be such an important date with regard to the completeness of dose records for DOE workers. [Rabovsky, 2017]

SC&A's 2017 ER Addendum review (SC&A, 2017a, p. 4) concluded with the following question and summation:

> **The more important question is the extent to which implementation of onsite programs was upgraded to conform to these new requirements and program expectations.** If LANL or other site radiological programs did not adhere to DOE Order 5480.11 . . . in terms of individual radiological monitoring at 100 mrem potential in 1 year (and for other required programs, e.g., radiation work permits (RWPs) and bioassays), would they have done so later under 10 CFR Part 835? . . .
>
> In summary, while 10 CFR Part 835 provides a clear regulatory milestone with the Department's first enforcement mechanism, it was one of several policy milestones for DOE's occupational RPP, with the basic provisions being first defined in DOE's 1989 Order 5480.11. **By itself, this regulatory milestone does not necessarily guarantee conformance with program requirements and expectations for individual monitoring, no more than did Order 5480.11 and the Radiological Control Manual before it.** If anything, core requirements for and change to how DOE internal dosimetry programs were implemented did not come until the internal dosimetry technical standard of 10 CFR Part 835 was coupled with an accreditation requirement (for overall dosimetry program functionality) under DOELAP in the 1998 amendments to the rule, which required all sites to achieve accreditation by January 1, 2002. [Emphasis added.]

SC&A's 2017 review surfaced a LANL self-assessment of its internal dose evaluation program (IDEP), conducted on March 22–25, 1999, by representatives from SRS, MJW Corporation, and LANL's ESH organization. This review was prompted by a DOE-wide 120-day enforcement moratorium (December 1998 through March 1999), founded on DOE's findings of widespread noncompliance associated with contractor IDEPs at various sites (e.g., Mound, SRS). It was intended to encourage an in-depth self-appraisal by each DOE site to identify deficiencies in their IDEPs and to undertake corrective actions.

The 1999 LANL self-assessment, self-reported to DOE as NC ID 484, cited 11 internal dosimetry program deficiencies, including (1) workers not accurately completing their health physics checklist, to the extent "that these checklists may not identify those radionuclides actually handled by the worker," leading to some workers not being assigned to the appropriate routine bioassay program; (2) radiological workers "not complying with specific RWPs that require them to participate in a bioassay program" (a sampling of RWPs found that for one specific RWP, two out of five workers did not submit required bioassays); and (3) the "principle [sic] subcontractor to Los Alamos National Laboratory, may not be enrolling all workers who are potentially exposed to radionuclides into the appropriate bioassay program in accordance with site requirements" (DOE, 1999, p. 2).

Compounding the finding of inaccurate or incomplete checklists was the LANL self-assessment concern that "bioassay requirements are not explicitly stated in work control documents such as radiological work permits and standard operating procedures. **This combination results in workers being on inappropriate bioassay programs**" (LANL, 2017a, PDF p. 136; emphasis added). Regarding the second finding from NC ID 484 described in the previous paragraph, the assessment team noted that "Five individuals were randomly chosen from a 1998 RWP that required workers to be on the Pu access list." However, it was pointed out in that assessment that

"one of the five had not submitted a [bioassay] sample since 1994 and a second had **never participated in a bioassay program**" (LANL, 2017a, PDF p. 136; emphasis added).[20] Regarding the third finding cited in NC ID 484, "discussions with a JCNNM [Johnsons Controls Northern New Mexico] supervisor indicated that JCNNM had completed HP checklists in the past but they were often returned due to lack of information. JCNNM then **stopped submitting them** because they didn't know the specific quantities of material being used or where the employees might be working" (LANL, 2017a, PDF p. 136; emphasis added).

To put the preceding in perspective, the HPCs were a key management means to identify radiation workers who needed to be enrolled in bioassay monitoring due to work-related exposure potential, and to ensure that any job or exposure changes were reflected in updated monitoring. The PAL listing verifies that a worker is on a plutonium monitoring program, which was required before performing any work involving plutonium processing operations at LANL. Johnsons Control was the primary maintenance and construction subcontractor at LANL and lacked bioassay enrollment for those workers not already participating in prescheduled internal dose monitoring programs. SC&A maintains that these were not minor or administrative noncompliances but rather ones that substantively impacted the adequacy of LANL's bioassay program.

RPRT-0102 is premised on justifying a co-exposure model for routine plutonium bioassay data and demonstrating the sufficiency of routine bioassay data for DR purposes. However, the work group and SC&A do not and never did have a concern over that issue from an SEC standpoint. As outlined in section 1.2 of this report, while the context of the NC ID 484 findings revolves around the routine plutonium bioassay program, its sitewide implications for the adequacy and completeness of nonroutine internal exposure sources, particularly the exotic radionuclides that figured in the SEC designation for 1976–1995, is what drove the request by the work group for NIOSH followup on this concern. SC&A has always concurred that sufficient routine data for plutonium and potentially some of the other primary radionuclides exist to support a co-exposure model (or alternately, the 100 mrem/year bounding dose), and made that clear in its 2018 joint presentation with NIOSH to the full Advisory Board: "Lack of substantiation that 100 mrem/year CEDE bounds unmonitored intakes of exotics after 1995; **available evidence supports only primary radionuclides**" (SC&A, 2018b, slide 15; emphasis added).[21]

Furthermore, the analysis in RPRT-0102 is designed around two assumptions (NIOSH, 2022, slide 6):

[20] This is noteworthy because, as NIOSH notes in RPRT-0102, "RWPs with plutonium access list (PAL) checked required that a person be on a plutonium monitoring program before performing work under the RWP" (ORAUT, 2021, p. 16). Given gaps identified for these mandatory bioassays, it is legitimate to question the completeness of bioassays for work involving non-plutonium exotics that were of lesser focus by LANL and more intermittent from an operational standpoint.

[21] Notwithstanding this supposition, the surfacing of NC ID 484 raised questions of bioassay data completeness and representativeness for both routine and nonroutine (e.g., RWP job-specific bioassays) exposures at LANL. There are several key concerns in how NIOSH has applied its metrics for showing RWP-related job-specific bioassay compliance and, therefore, data completeness (i.e., findings 4, 5, and 6 and observations 4 and 5).

- Bioassay programs for plutonium are specifically addressed because plutonium posed the greatest radiological hazard to workers at LANL during the study period (1996 to 2001)

- If LANL was correctly monitoring for plutonium what evidence makes us think the monitoring was different for other radionuclides of concern

SC&A agrees that plutonium at LANL was of most concern from a radiological hazard standpoint during the time period in question but disagrees that conclusions about the routine monitoring program for plutonium (and potentially other primaries) necessarily carry over to exotic radionuclides. LANL rigorously applied plutonium monitoring under its PAL, which made monitoring a prerequisite for working in operations or facilities where plutonium was being handled. Notwithstanding this level of program priority and presumed accountability, the 1999 self-assessment found in a very limited sampling that two of five PAL-covered plutonium workers lacked bioassay coverage. NIOSH's later survey of available RWPs involving plutonium found that 14 percent on average likewise showed no corresponding bioassays (28 percent for Johnson Controls, the primary maintenance subcontractor) (ORAUT, 2022a). Furthermore, bioassay monitoring for plutonium was found deficient in at least two DOE independent program assessments at that time: (1) NC ID 715, involving "Routine Pu Bioassay Program Weakness," issued in 1997 (DOE, 1997), and (2) NC ID 1219, involving "Personnel Dosimeter Assignment,"[22] issued in 2002 (DOE, 2002).

As noted in section 3.3, bioassay data were lacking for exotics during the SEC designated period of 1976–1995 despite identified operational source terms, a monitoring concern that extends into the 1996–2005 time period in question. In this context, SC&A continues to be concerned over findings of lack of proper bioassay enrollments due to inadequate or missing HPCs (coupled with lack of facility exposure assessments and with bioassay requirements not being typically included in work control documents such as RWPs), and lack of responsiveness by supervisors and workers in evaluating and establishing RWP-required job-specific bioassays. In fact, as illustrated by SC&A's review of RPRT-0103 (section 2.3), there were very few available RWPs that included a job-specific bioassay requirement beyond that covered by the prescriptive PAL checkbox. This clearly would have been of particular consequence for radiological work with exotic radionuclides because such work was intermittent, often experimental and bench scale, very job specific at LANL, and may have involved the Johnsons Control subcontractors who lacked adequate enrollment.

Finding 8. The results in RPRT-0102 for routine plutonium monitoring are not transferable to nonroutine, job-specific sampling for exotics, which was much more discretionary and based on individual line management or RCT judgments about job-related exposure potential.

[22] Notwithstanding the title of this noncompliance report, NC 1219 involved a LANL self-assessment that employed its newly adopted facility matrices to survey 99 workers at TA-55 to ascertain whether they were on the appropriate internal and external dosimetry, with a finding that workers were on less conservative than required bioassay attributed, in part, to line managers failing to consistently perform internal dosimetry evaluation reviews for all workers (DOE, 2002).

3.5 Validating actual upgrades to bioassay program implementation

In terms of corrective actions for the 1999 NC ID 484 monitoring program deficiencies, LANL developed and implemented a sitewide, web-based Dosimetry Participation Verification Program (DPVP) to ensure that operational line managers and health physics personnel oversaw and updated dosimetry enrollment information for all LANL workers. This information identified the routine bioassay programs that individuals were enrolled in and permitted health physics staff to identify gaps or inconsistencies in enrollments. The DPVP was effective at LANL on October 1, 2000 (DOE, 1999).

To ensure LANL workers were enrolled in appropriate bioassay programs, LANL also developed and implemented online facility-specific and activity-specific dosimetry matrices, which provided standardized bioassay enrollment criteria, as well as an archival record of dosimetry assignments. This was supplemented by other requirements and procedural tools such as the 1999 "Internal Dosimetry and Bioassay Requirements for LANL Operations," which prescribed minimum detectable dose equivalents for secondary radionuclides, including exotics. Following piloting of the matrices and new enrollment process at selected facilities, it was rolled out to the entire laboratory on October 23, 2000 (DOE, 1999).

As characterized by LANL in 1999 (LANL, 2017a, PDF p. 58), this

> new, robust program could help ensure proper enrollment of workers from both the Laboratory and its subcontractors. This program is comprised of three major components. The first component is the development and implementation of a technical basis document that specifies those generic work activities and quantities and types of radionuclides that will likely result in exceeding the bioassay monitoring threshold of 100 mrem CEDE in one year. The second component is a crosswalk between these generic work activities and quantities and types of radionuclides and work activities in specific facilities and other areas of the Laboratory. In other words, the second component defines those work activities in specific facilities that will likely result in greater than 100 mrem/year CEDE. Operational health physics team leaders in ESH-1 will establish the crosswalk. The first and second components would be used to produce "facility-specific matrices" that provide bioassay program assignment requirements for work in specific facilities and other areas of the Laboratory. The third component is the assignment of workers to these specific bioassay programs by their managers based on the types of work activities performed by the worker.

These internal dosimetry program upgrades provided a uniform and consistent sitewide means for LANL line managers and healthy physics staff to verify bioassay status and to ensure that (1) workers were enrolled in the correct bioassay programs and (2) all workers were abiding by both routine and nonroutine bioassay requirements. This was reinforced by training of both managers and workers. These sitewide corrective actions were subject to review and validation by DOE as the basis for closing out the 1999 enforcement action; DOE did so on February 27, 2001. To repeat NIOSH's admonition in this regard (NIOSH, 2018a, pp. 6–7), this is the **first time** that there was a demonstrable and verifiable "program in place ensuring that unmonitored workers were unlikely to receive intakes resulting in 100 mrem CEDE."

As noted earlier, SC&A's objective is to go beyond the "designated" effective date of 10 CFR Part 835 implementation at LANL (January 1, 1996)—a milestone that NIOSH assumes corresponds with "the health physics field monitoring and contamination control programs at LANL [being] well established and formalized" (ORAUT, 2022a, p. 9)—to ascertain when programs were actually modified, when managers and workers were aware of and trained on these changes, and when adequate implementation was achieved. To do so, SC&A reviewed a series of LANL self-assessments performed under the aegis of the DOE Price Anderson Act enforcement program in order to validate the effectiveness of the program upgrades and corrective actions accomplished in 1999–2000.

The following two assessments of the LANL internal dosimetry monitoring program are relevant to this validation review, as follows.

- **DOE-Los Alamos Area Office (LAAO) programmatic assessment of LANL internal dosimetry program,** January–February 2001 (DOE, 2001):

  This assessment, conducted by the Office of Facility Operations of DOE's Los Alamos Area Office, "evaluated LANL's compliance with the internal dosimetry requirements promulgated in Subpart C of 10 CFR 835 and the flow down of these requirements in the implementing documents for LANL's internal dosimetry program" (DOE, 2001, PDF p. 8). DOE noted that if a finding is made, it is "defined as an aspect of the internal dosimetry program that the assessment team believes prevents the program from functioning competently" (DOE, 2001, PDF p. 8). Specific focus was provided to program performance against 10 CFR 835.402(c)(1-4), governing internal monitoring of individuals likely to receive 100 mrem/year CEDE.

  DOE found that "the majority of the line managers interviewed had not performed the annual review of the status of personnel in the routing [sic, routine] bioassay program as required by the requirements in LIR 402-706-01.1 [LANL's monitoring procedure]" (DOE, 2001, PDF p. 10). This LANL procedure required a routine facility-by-facility review to ensure that individual bioassay requirements for all radiation workers were kept up to date and appropriate for the exposure involved. However, most of the line managers interviewed were not aware of the requirement and found that doing so using the paper "health physics checklist" to be "cumbersome" (DOE, 2001, PDF p. 11). It was subsequently pointed out to the managers by LANL safety management that the new automated enrollment system (implemented in October 2000) would make it easier to "ensure that all workers performing similar radiological operations are enrolled into the proper element(s) of the internal dosimetry program" (DOE, 2001, PDF p. 11).

  LANL's Radiation Protection Program Manager responded to this finding on August 2, 2001, and provided a list of corrective actions to ensure line management accountability and responsiveness to its responsibilities for implementing laboratory bioassay monitoring procedures (LANL, 2001).

- **NC ID 1219,** February 2002 (DOE, 2002):

  Prompted by discrepancies in an online dosimetry reporting system, a LANL investigation found software connectivity issues that had led to incorrect listings of dosimetry assignments. Concurrently, LANL conducted a validation survey on the accuracy of its recently implemented (October 2000) facility dosimetry matrices, which were designed to "match dosimetry assignments in each facility with the type of work being performed, types and quantities of radioactive materials handled, and the types of areas entered" (DOE, 2002, p. 2). A sampling of 99 workers at TA-55 (LANL's plutonium processing facility) for internal and external dosimetry found that 31 were on the correct dosimetry programs, 31 were on more conservative programs, and 23 were on "less conservative than required dosimetry" programs, with the remaining 14 in the process of terminating from inclusion in the programs (DOE, 2002, p. 2). The 23 workers (about a quarter of those sampled) on less conservative dosimetry was reported as a noncompliance with 10 CFR 835.402(a)(1) and 835.402(c)(1), governing requirements to monitor workers likely to receive an external or internal dose of 100 mrem CEDE, respectively.[23]

  In its presentation before the Board in August 2017 regarding NC ID 1219, NIOSH attributed workers being on "a less conservative bioassay program than required" as being "caused by a computer software problem" (NIOSH, 2017b, slide 18). This statement is not accurate given that beyond an initial investigation of the software application issues involved (issues were found, but [Redacted] that had led to incorrect enrollments), LANL also conducted a "further test to evaluate the accuracy of the on-line report and to determine if individuals were properly assigned to the appropriate internal and external dosimetry programs based on facility dosimetry matrices" (DOE, 2002, p. 2). LANL notes that "these matrices match dosimetry assignments in each facility with the type of work being performed, types and quantities of radioactive materials handled, and the types of areas entered" (DOE, 2002, p. 2). This was the source of the bioassay monitoring sampling results presented in NC ID 1219. Coupled with LANL's finding that there was an apparent failure of line management to consistently perform internal dosimetry evaluation reviews for all workers,[24] LANL was not implementing its responsibilities under LIR402-700-01 and 10 CFR 835 to ensure that all workers were monitored who had a potential exposure of 100 mrem/year CEDE.

  As noted by DOE (DOE, 2002, p. 3), based on LANL input:

  > The Laboratory had been in transition from an older, less formal, dosimetry assignment process (Health Physics Checklist) to a more formal enrollment system using the dosimetry matrices. Although the new system

[23] A review of self-assessment backup information shows that the discrepancies were centered on bioassay underenrollments (LANL, 2017b).

[24] The review process "must be repeated annually and upon hiring into a new position, upon changing a job assignment that results in a change in dosimetry, upon declaring pregnancy, upon rehiring into a position, and when visiting the Laboratory in areas posted for radiological hazards" (DOE, 2002, pp. 2–3).

> had been advertised within the Laboratory, it is possible that not all potentially affected managers became aware of the new enrollment system and the requirement for reviews of worker dosimetry assignments annually and based on other specific criteria.
>
> Given that dosimetry requirements and systems have evolved recently and that tools to help with implementation were only recently reliable, it was appropriate to assess implementation at this time. Corrective actions are being aggressively pursued, and this was quickly self-identified as a regulatory non-compliance issue.

On December 15, 2002, a new LANL policy was implemented making worker participation in radiation protection dosimetry programs a precondition for security access to the Laboratory. As a follow up to this and other accountability initiatives, it was reported, on September 18, 2003, that "after 6 months of use, dosimetry assignment was again reviewed and no errors were found" (LANL, 2002, PDF p. 7). The noncompliance report was closed by DOE on March 15, 2004.

While LANL was later cited for a series of unrelated program deficiencies for its work planning (including application of RWPs) and radiological controls, these did not include any further concerns related to the bioassay program and its implementation in the timeframe following the implementation of the DPVP and dosimetry enrollment matrices in 2000–2001.

3.6 Weight of evidence regarding bioassay monitoring of exotics

In its conclusions in RPRT-0101 for bounding intakes of exotic radionuclides at Los Alamos National Laboratory, ORAUT includes the following weight-of-evidence conclusion:

> In this report, the ORAU Team has discussed the LANL radiological control program and demonstrated that contamination was well controlled in TA-3, TA-48, and TA-53. Data evaluated in Section 3.0 shows that LANL controlled routine contamination that could lead to doses greater than 100 mrem at all three TAs. While data used in the report are not the total set of data collected by LANL, the **weight of evidence** supports that premise. The ORAU Team has shown that LANL operated a radiation protection and control program that included the use of portal monitors to identify and remediate workplace radiological contamination. LANL Health Physics responded to even small levels of contamination. [ORAUT, 2022a, p. 27, emphasis added]

SC&A believes any such "weight of evidence" argument, in order to be valid in this context, needs to be founded on objective evidence that is based on more independent and evaluative considerations, as follows:

- **Actual validated operational practice or experience, versus program descriptions, procedures, or organizational intent:**

  It is important to gauge bioassay program performance by actual LANL bioassay monitoring experience, not solely by expectations as defined by written procedures or by

sampled records regarding the functioning of contamination control programs. The 1999 self-assessment performed by LANL was in response to a DOE-wide moratorium in 1998–1999 for enforcement actions against DOE contractors to enable them to self-assess and, as necessary, make corrective actions for their internal dose evaluation programs in the face of widespread deficiencies in implementing and enforcing those programs in accordance with site policies and procedures and 10 CFR Part 835. The development and rollout of the DPVP and facility enrollment matrices in 2000–2001 were designed to correct for longstanding deficiencies in LANL's bioassay program implementation, ones that had persisted at the laboratory through various upgrades to previous radiological control policies and procedures. Given this history, the effectiveness of radiological monitoring needs to be gauged by actual performance assessments, experience, and results, not solely by descriptions of operational health physics practices (e.g., worker use of portal monitors and conduct of contamination control), existing monitoring procedures, and the presence of monitoring technology and protocols. Cited program policies and procedures likewise need to be based on the time period in question, 1996–2005, not later periods when more mature radiological control programs were backed by more contemporary program documentation.[25]

- **Objective and representative sampling versus subjective or selective sampling of monitoring results – data should be representative of time, location, and job tasks:**

  To form a valid sampling basis for demonstrating that contamination surveys or air concentrations would not have exceeded 100 mrem/year CEDE, some means of adequately representing the facilities, timeframe, and actual measurements performed are necessary. Requirements under 42 CFR 83.13(c)(ii) provide that, "at a minimum, that NIOSH have access to reliable information on the identity or set of possible identities and maximum quantity of each radionuclide (the radioactive source material) to which members of the class were potentially exposed without adequate protection."

  RPRT-0101 notes, and SC&A agrees, that RPRT-0101 is not based on a complete dataset either by location or by year, and the overall level of completeness is unknown. As SC&A notes in findings 1 and 2 of this review, the captured and transcribed dataset is not

[25] For example, Archuleta (2022) is cited frequently in RPRT-0103 to describe LANL radiological program practices for the operational time period in question, 1996–2005. Archuleta (2022) references LANL Technical Issue Paper (TIP)-007, "Algorithm for Monitoring," issued on May 26, 2005 (at the very end of that timeframe), and TIP-018, "Bioassay Program Enrollment Criteria," issued on October 19, 2006. The appendices provided to support Archuleta (2022) are likewise all dated over the past 18 years and not contemporary with the SEC period in question (1996–2005). While it is claimed by LANL that "these statements [for program descriptions and procedures made in these references and cited in RPRT-0103] represent current expectations **and those during the time period under review**" (Archuleta, 2022, PDF p. 8; emphasis added), no corroboration is provided that these expectations were formally defined in procedures and carried out for the earlier time period. It needs to be stressed that the time period 1996–2005 was one of significant change in how the LANL internal dosimetry program was defined by procedure and implemented by both the radiation protection and line programs. LANL implementation of required internal dose monitoring, particularly in the 1996–2001 period, was found to be fundamentally deficient by the laboratory's own self-assessment in 1999 and noncompliance reporting under 10 CFR Part 835, a programmatic shortcoming that was not corrected until at least late 2000.

meant to be evaluated by any established statistical measure, as it is not considered a random nor a representative sample of the survey and air concentration data surveyed.

As noted in finding 3 of this review, SC&A found that the examples of routine monitoring instructions intended to demonstrate contamination surveying and air monitoring responsibilities were dated as taking effect in the year 2000 or later (except for the one for TA-48, which was effective July 1997). Additionally, examples of incidents in 1996 with fixed monitoring stations used to control contamination at location entrances were for TA-55, which is the plutonium facility and may not be representative of the facilities where exotics were handled.

Another question, unanswered, is whether the area contamination and air concentration surveys for exotic radionuclides, which are general area measurements, can be readily converted to an equivalent 100 mrem/year CEDE intake level. While these surface contamination levels and general air concentration levels appear relatively low and have been found typically less than 100 mrem/year CEDE in RPRT-0101, would they be so for the breathing zone of workers in nonroutine operational circumstances? The subject of applying general air concentration measurements in this manner was raised as a concern by NIOSH in comments made to the work group (ABRWH, 2018, p. 59).

- **Independent or external means of assessing radiological control program performance should be emphasized:**

  As acknowledged by LANL, DOE, and the U.S. General Accounting Office (GAO)[26] just before, within, and following the timeframe of SEC concern, a root cause of LANL's longstanding program deficiencies in radiation protection, facility operations, and security programs was a workplace culture resistant to change. In such instances, which were likewise common at other DOE sites during the 1980s and 1990s, the long-tenured operating contractors responsible for radiological control were effectively blind to, or disbelieving of, persistent program deficiencies; resistant to or unfamiliar with mandated program upgrades; or were unable to effect necessary and lasting corrective actions. Under such circumstances, the only reliable representation of actual LANL program performance would arguably be assessments conducted by independent or external professionals whose radiological monitoring policy and program perspectives were broader than those within LANL at the time. The 1999 self-assessment embodied in NC ID 484 exemplifies such an outside perspective, as do other program self-assessments and audits, and external oversight reviews of the LANL radiological control program. These need to be given particular weight in any determination regarding the status of LANL radiological control program adequacy and **on-the-ground** responsiveness to corrective actions. While external oversight reviews are a "blunt" tool in this regard, as pointed out by SC&A (SC&A, 2017a, p. 3), self-assessments by the laboratory under the aegis of the enforcement program are one of the few meaningful measures of whether,

[26] For example, DOE (1991), pp. ES-1–ES-2; LANL (2000b), pp. 9, 15; DOE (2003), PDF pp. 17–20; DOE (2004a), pp. 3–4; and GAO (2007).

and when, LANL was adequately implementing its bioassay monitoring program such that potential exposures of 100 mrem CEDE were being adequately monitored.

SC&A's weight of evidence conclusions, which follow, assign significance to that evidence and information that satisfies the above considerations.

3.7 NIOSH programmatic conclusions and SC&A updated response

The following subsections are SC&A's summary of NIOSH's programmatic conclusions for each of the three assessment reports, followed by SC&A's response.

3.7.1 ORAUT-RPRT-0101

3.7.1.1 NIOSH conclusions

Weight of evidence clearly indicates that worker doses due to unmonitored exotic radionuclides would not likely have exceeded 100 mrem/year. Doses for workers monitored by bioassay can be bounded using bioassay results.

3.7.1.2 SC&A response

SC&A agrees that the RPRT-0101 results for converting routine survey data from the three LANL facilities to projected intakes and internal dose indicate that projected internal doses would not have likely exceeded 100 mrem/year CEDE for the specific locations and timeframes indicated. However, RPRT-0101 notes, and SC&A agrees, that that report is not based on a complete dataset either by location or by year, and the overall level of completeness is unknown (findings 1 and 2). Likewise, as noted in finding 3, examples of routine monitoring instructions intended to demonstrate contamination surveying and air monitoring responsibilities were dated as taking effect in the year 2000 or later (except for the one for TA-48, which was effective July 1997), with examples of incidents in 1996 with fixed monitoring stations being for TA-55, which handled plutonium, not exotics, during the period of interest. Furthermore, as SC&A observes, the captured and transcribed dataset is not meant to be evaluated by any established statistical measure because it is not considered a random nor a representative sample of the survey and air concentration data surveyed.

SC&A does not agree that the scope of evaluation should be confined to "workers doing routine work, such as guards and custodians," as provided by RPRT-0101, with such routine work being "defined as work not done under a radiation work permit (RWP)" (ORAUT, 2022a, p. 7). Nonroutine exposures, in fact, characterize the intermittent nature of much exotic handling at LANL, as noted by NIOSH in its basis for the prior SEC class recommendation for 1976–1995 (ABRWH, 2012c, pp. 11–12). Observation 1 of this report notes that a clear specification of the worker job types and radionuclides covered by the 100 mrem approach is warranted to clearly delineate between the RPRT-0101 approach and any future development of co-exposure models for unmonitored workers who should have been monitored or whose records are unavailable. As it stands, the scope of evaluation for internal exposure to exotics, and even the definition of exotics being applied, has apparently shifted over the course of the work group's review since 2012. This definition slip bears further discussion within the work group.

Another question is the conversion of general area samples to breathing zone intakes. Past experience has shown that general survey data (e.g., room contamination readings and general air

samples) do not necessarily equate to actual worker intakes (i.e., breathing zone exposures). At the very least, a conservative conversion factor should be added to address that issue, as originally suggested by NIOSH (ABRWH, 2018, p. 59).

Finally, SC&A disagrees that the strength of LANL radiological controls can be founded on LANL "operat[ing] a radiation protection and control program that included the use of portal monitors to identify and remediate workplace radiological contamination" and "requir[ing] workers exiting Contamination Areas, High Contamination Areas, Airborne Radioactivity Areas, and RBAs to frisk for contamination" (ORAUT, 2022a, p. 27). As noted earlier, maintenance of a functional field contamination control program does not bear on whether line management maintained an adequate bioassay program consistent with 10 CFR Part 835 monitoring requirements for worker bioassay identification and enrollment.

3.7.2 ORAUT-RPRT-0102

3.7.2.1 NIOSH conclusions

A preponderance of evidence supports the conclusion that the plutonium bioassay data reported by LANL in the 1996 to 2001 study period include a significant portion of the most highly exposed workers and, therefore, are adequate to construct a co-exposure model for plutonium.

3.7.2.2 SC&A response

SC&A conditionally accepts that a co-exposure model for plutonium may be constructed for LANL for 1996–2005 based on the amount and availability of routine bioassay data for those years and its representativeness for exposure potential. Both the work group and SC&A had agreed in 2017 that there was a clear distinction between the availability of routine bioassay data for the primary radionuclides at LANL, including plutonium, and for nonroutine exposures to exotics. However, NC ID 484 raised questions of bioassay data completeness and representativeness for both routine and nonroutine (e.g., RWP job-specific bioassays) internal exposures. In addition, SC&A identified concerns with how NIOSH constructed its metrics in the context of establishing compliance with the RWP bioassay program.

These include:

- Finding 4, where SC&A does not agree that an individual worker should be considered compliant with RWP bioassay requirements if ANY of the RWPs associated with that individual during the year have appropriate associated plutonium bioassay

- Finding 5, where SC&A does not believe the NIOSH assumption of an appropriate time window for bioassay submission—during the RWP work or by the end of the year after the year in which the RWP expired—is an appropriate metric for assessing monitoring compliance with RWP-related work

- Finding 6, where SC&A finds that the assumed connection between exposure potential for workers based solely on signing the same RWP acknowledgement form is questionable

SC&A finds that application of these questionable metrics belies a more reasoned and conservative approach to establishing RWP job-specific bioassay data completeness, which would be based on verified implementation of established LANL bioassay program policy and practice during the time period in question.

Notwithstanding even an "open window" approach (ORAUT, 2021, p. 26), NIOSH found that 14 percent of even the PAL-mandated plutonium bioassays for 1996–2001 were not apparently performed during that period (28 percent overall for Johnson Controls), which raises concerns over radionuclide sources of historically lesser priority and prevalence, such as exotics. As noted in observation 5, SC&A does not agree with NIOSH's contention that the majority of these missing bioassays can be explained under legitimate reasons to excuse nonsubmission of a sample request.

3.7.3 ORAUT-RPRT-0103

3.7.3.1 NIOSH conclusions

ORAUT's review of 24 example RWPs from three facilities concludes that "LANL Health Physics, via intermittent RCT and/or continuous RCT coverage, appropriately monitored jobs [involving exotic radionuclides] covered by RWPs" (ORAUT, 2022b, p. 33). NIOSH also concludes that "the review of these RWP packages supports the premise that LANL Health Physics personnel monitored workers for nonroutine radiological work conditions and radiological situations, reinforcing the conclusion in RPRT-0101 that [workers would not likely have exceeded 100 mrem/year]" (ORAUT, 2022b, p. 33).

3.7.3.2 SC&A response

SC&A agrees that LANL performed routine contamination control and monitored its workers for radiological conditions for specific work covered by the RWPs selected. However, SC&A disagrees that this very limited and subjective review of RCT coverage and contamination control functions addresses the fundamental issue raised by NC ID 484 as it pertains to exotic radionuclides: From a data analysis standpoint, does the bioassay incompleteness identified in the limited sampling in 1999 reflect a broader incompleteness in LANL's bioassay monitoring for 1996–2000? From a program standpoint, did LANL line management adequately perform facility and job exposure characterizations to identify needed bioassays and ensure proper bioassay enrollment of workers for potential internal exposures, notably, for exotics? These questions go to the completeness of nonroutine bioassays and whether the 100 mrem/year threshold for monitoring (and NIOSH's proposed bounding dose) was being applied for exotic radionuclide sources adequately and consistently. While for plutonium monitoring there may be sufficient, representative data to support a co-exposure model, that is not the case for dose reconstructing internal exposures to exotics at LANL using a bounding dose for unmonitored workers, an issue that was at the root of the Board's recommendation for and designation of the 1976–1995 SEC class.

4 SC&A Summary and Conclusions

In response to issues raised by the NC ID 484 self-assessment, in 2018 "NIOSH committed to reviewing RWPs and developing a sampling plan for determining whether workers were complying with bioassay requirements and what affect [sic] that may have on dose reconstruction [for 1996–2000]" (NIOSH, 2022, slide 4). Concurrently, both NIOSH and SC&A interviewed LANL senior health physicists who were present at the time of the self-assessment to see if they had done further evaluation to determine the magnitude of people not leaving bioassay samples as required and found that "nothing [was] done at the time to determine the magnitude of individuals not leaving the required bioassay" (NIOSH, 2019b, slide 4). As noted by NIOSH, LANL staff indicated that they recognized issues with the HPC and made a decision to "fix things going forward" as part of the LANL corrective actions (NIOSH, 2019b, slide 4). As noted previously in this report (section 3.5), the corrective actions were completed in October 2000 and closed by DOE in February 2001.

However, with access to available LANL RWPs for the period in question, NIOSH made a decision not to conduct the RWP sampling for job-specific bioassay data completeness and, instead, to review the routine bioassay database in hand. A new study plan was designed to answer the question: "Do the indicated bioassay program deficiencies imply data inadequacy and incompleteness significant enough to impair development of a co-exposure model?" (ORAUT, 2021, p. 7). NIOSH's revised review encompassed available routine plutonium bioassays (including RWP-related job-specific bioassays) and related checklist forms and compared those with bioassays in LANL's BEST system.

As noted earlier in this review, neither the work group nor SC&A has taken issue with the capability to dose reconstruct routine internal dose for the primary radionuclides (e.g., plutonium). Instead, the concern has been whether the program gaps identified in 1999 had sitewide implications prior to LANL's corrective actions in 2000, particularly for nonroutine, RWP-related exposure potential and appropriate internal monitoring for exotic radionuclides.

RPRT-0101 does not address bioassay data completeness. RPRT-0101 addresses whether doses from exotics would likely exceed 100 mrem/year based on a survey of general room airborne levels and surface contamination data for three specific LANL facility locations, coupled with contamination control program descriptions. RPRT-0103 provides 24 example RWPs to "support the premise given in RPRT-0101 that LANL monitored work so they could determine which workers to monitor by bioassay" (ORAUT, 2022b, p. 7). NIOSH acknowledges that RPRT-0103 is subjective, not intended to provide a degree of statistical confidence, and does not provide dose assessments for workers named in the RWPs.

While SC&A agrees that exotic radionuclides are relatively rare when compared with the primary radionuclides at LANL, they remained a substantive aspect of laboratory radiological control involving isotope production, research, and development (e.g., LANSCE); waste management and processing (e.g., CMR); and legacy contamination (e.g., TA-48). While the RPRT-0101 sampling survey indicates no likely exposure potential for the three facilities in excess of 100 mrem/year for the locations sampled, neither it nor RPRT-0103 gauged whether LANL adequately assessed internal exposure potential to exotics at 100 mrem/year CEDE and addressed to what extent nonroutine bioassays were complete.

Unlike plutonium bioassay, LANL facilities that handled exotics did not have a mandatory PAL system that prescribed monitoring as a condition for working in plutonium processing facilities.[27] The lack of available bioassays and enrollments cannot be simply attributed to LANL following its precept that these were on an "as-needed basis" and only "for radiological workers likely to receive 100 mrem annually from internal exposure to radionuclides (i.e., 100-mrem monitoring threshold)" (LANL, 2013, PDF p. 3). It has been made clear by NC ID 484, LANL's corrective action program, and LANL management statements that the existing bioassay program in 1999 was flawed because its administrative procedures and systems did not hold line managers and workers accountable to its adequate implementation. Without adequate implementation of health physics checklists and job and facility exposure assessments (e.g., in the facility matrices), line management would not necessarily have identified operational sources of potential exposures for exotic radionuclides exceeding 100 mrem/year CEDE, which would have led to incomplete monitoring. Unlike for plutonium, there is no available means to validate that the "radiological workers likely to receive 100 mrem annually" for such exposures would have been represented in what little bioassay data do exist, enabling a co-exposure model to be developed.

It is recognized that an acceptable level of completeness and the degree to which the data are sufficiently representative of the unmonitored population are currently subjective decisions and a matter of professional judgment. For example, an SEC class was recently recommended by the Board and designated under SEC-0103 (Savannah River Site) for subcontract workers because it was determined by the Board that RWP-based monitoring was insufficiently complete to formulate an appropriately representative co-exposure estimate for that population, despite a significant amount of routine monitoring data available. Currently, the SEC Issues Work Group is undertaking the issue of subjective decisions on completeness and representation to determine if there is a way to quantify the evaluations consistently throughout the program. However, that work has not been completed to date, and so it is not clear at this time if a standard objective measure of completeness and representation is feasible.

SC&A Summary Conclusion: LANL-wide programmatic implementation of the requirement at 10 CFR 835.402(c)(1) for monitoring of potential internal exposures of 100 mrem/year CEDE, the basis for NIOSH's proposed bounding dose for unmonitored workers during 1996–2005, is found to be of questionable adequacy, with major deficiencies not corrected until at least the end of 2000. This inadequacy undercuts the use of that threshold dose as bounding for unmonitored worker exposure to MAPs, MFPs, and other exotic radionuclides.

[27] And even in this case, the 1999 self-assessment found that two of the five workers under PAL had not submitted bioassays, one for almost 5 years. In NIOSH's review of HPCs versus BEST enrollments, 14 percent of workers under PAL had not submitted the mandatory bioassays as scheduled.

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