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Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

Review of NIOSH Response to SC&A on ORAUT-RPRT-0092, Revision 00, on Bioassay Data for Subcontracted Construction Trade Workers at the Savannah River Site

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Prepared by

Robert Barton, CHP
Ron Buchanan, PhD, CHP
Joe Fitzgerald, MS, MPH

SC&A, Inc.
2200 Wilson Boulevard, Suite 300
Arlington, VA 22201-3324

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Abbreviations and Acronyms

ABRWH, Advisory Board	Advisory Board on Radiation and Worker Health
Am	americium
ANSI	American National Standards Institute
Ce	cerium
CFR	Code of Federal Regulations
Cs	cesium
CTW	construction trade worker
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
DPSOL	DuPont Savannah River Operating List
DPSOP	DuPont Standard Operating Procedure
EE	energy employee
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
GM	geometric mean
GSD	geometric standard deviation
H	hydrogen
HP	Health Protection (department)
MPPF	Multi-Purpose Processing Facility
N/A	not applicable
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH Division of Compensation Analysis and Support Claims Tracking System
NSR	New Special Recovery facility
NTS	Noncompliance Tracking System
ORAU	Oak Ridge Associated Universities
ORAUT	Oak Ridge Associated Universities Team
OTIB	ORAUT technical information bulletin
PAAA	Price-Anderson Amendments Act
Pu	plutonium
RCO	Radiological Control Operations
RCI	Radiation Control Inspector

Ru	ruthenium
RWP	Radiological Work Permit
SEC	Special Exposure Cohort
Sr	strontium
SRDB	Site Research Database
SRS	Savannah River Site
SRTC	Savannah River Technology Center
subCTW	subcontracted construction trade worker
SWP	Special Work Permit
TBD	technical basis document
U	uranium
WSRC	Westinghouse Savannah River Company

1 Executive Summary

As part of its 2017 review of subcontracted construction trade worker (subCTW) job-specific bioassay completeness for Savannah River Site (SRS) (SC&A, 2017a), SC&A noted that a Westinghouse Savannah River Company (WSRC) self-assessment in 1997 found that 79 percent of permit-required, job-specific bioassays were missing. In 1998, the U.S. Department of Energy (DOE) cited and fined WSRC for not adequately monitoring workers performing radiation work under job-specific Radiological Work Permits (RWPs) (DOE, 1998a). While WSRC had resampled the subcontractors who lacked job-specific bioassays in 1997, there was no further review to ascertain the completeness of permit-indicated, job-specific bioassays for prior years. At the request of the Advisory Board on Radiation and Worker Health (Advisory Board), the National Institute for Occupational Safety and Health (NIOSH) agreed to conduct such an evaluation for 1972–1998 for various areas of SRS, with the results documented in ORAUT-RPRT-0092 (NIOSH, 2019a; "RPRT-0092"). SC&A first commented on RPRT-0092 in its November 2019 memorandum report (SC&A, 2019a). NIOSH presented an initial response at the December 5–6, 2019, joint meeting of the SRS and Special Exposure Cohort (SEC) Issues work groups, followed by a formal response on August 18, 2020 (NIOSH, 2020a). The following is SC&A's review of that recent response.

1.1 Late DuPont operational era

For the late DuPont operational era, covering 1972–1989/1990[1] of the qualified SEC petition period under review, SC&A continues to conclude that NIOSH (1) has been unable to demonstrate the completeness of subCTW job-specific bioassay data and (2) did not accomplish the objectives defined in its sampling plan for the RPRT-0092 analysis.

In its 2019 response (SC&A, 2019a), SC&A found the following for RPRT-0092's treatment of the DuPont era:

1. Lack of actual linkage between Special Work Permits (SWPs) and job plans (and even respiratory protection) and required followup bioassays – No evidence was found of job-specific bioassays being performed in response to SWPs or job plans, or prescribed respiratory protection.

2. Lack of SRS operational representativeness – Only building 773-A job plans and SWPs were found for 1972–1974 and 1980–1989, and none were found for 1975–1979.

3. Lack of procedural requirements or documented practice that required job-specific bioassays based on either SWPs or job plans, or respiratory protection – NIOSH already concluded that DuPont Standard Operating Procedure (DPSOP) (or DuPont Savannah

[1] While the DuPont operations contract at SRS ended on March 31, 1989, and NIOSH bifurcated its RPRT-0092 review into two periods, 1972–1989 and 1990–1998, SC&A found little permit documentation was identified for 1990, for unknown reasons. However, it should be noted that WSRC had just assumed management of the SRS operating contract and was in the process of implementing a new, formal Radiological Work Permit (RWP) system. Any SC&A conclusions for 1972–1989 would, therefore, also apply for 1990. Additionally, no job plans were identified after March 1988 in RPRT-0092. Therefore, throughout this report, SC&A refers to an "expanded" DuPont era ("1989/1990") extending through the end of 1990.

River Operating List (DPSOL)) procedures under DuPont were too "general" to be a basis for identifying permit-related, job-specific bioassays.

4. The back application of the Farrell and Findley (1999) source characterization criteria to identify relevant radionuclide source terms for DuPont era operations of 1972–1989 is not supported, given the widely varying radioactive materials being handled in earlier years and the lack of a routine, comprehensive characterization process available at that time.

Specific to the results presented in RPRT-0092 for this time period, SC&A believes that the assessment of job-specific monitoring based on the limited job plans for americium was not successful in establishing that subCTWs were adequately monitored. SC&A's evaluation of the data established that only 20 percent were directly monitored and only 13 percent of unmonitored workers were adequately represented by monitored workers on the same job plan who are included in co-exposure modeling for unmonitored intakes. This results in an effectively monitored population of only 33 percent. These results are further complicated by the fact that only one location (F-Wing of 773-A) was available for analysis of job-specific monitoring of separated americium with only a single job plan in 1973 (no associated internal monitoring) and the remaining job plans only covering the years 1981–1987. Job plans for other locations of potential exposures to separated americium exposures (i.e., the Multi-Purpose Processing Facility (MPPF) and possibly the New Special Recovery facility (NSR)) and years under evaluation (part of 1972, 1974–1980, 1988–1990) were not located for appropriate evaluation.

1.2 Westinghouse operational era

For the Westinghouse operational era, covering 1991–1998 of the qualified SEC period under review, SC&A concludes that subCTW job-specific bioassay completeness can be established, but with some qualifications that remain to be addressed. Most notable is defining when RWPs were sufficiently implemented such that job-specific bioassays can be adequately linked to subCTWs under those permits (e.g., with specific radionuclides and bioassays prescribed, even when respiratory protection was required) to demonstrate that lapses in subCTW job-specific bioassays in 1996–1997 are not apparent in prior years (1991–1995) and would not preclude co-exposure model inclusion of those data.

While RPRT-0092 provides relatively higher completeness rates (as compared to the earlier era at SRS) for subCTW job-specific bioassays for the 1991–1998 period, the validity of those rates remains questionable without addressing available evidence of actual bioassays being performed on the basis of individual RWPs and defined source terms. Given the WSRC program deficiency on this issue in 1996–1997, leading to DOE enforcement action in 1998, it remains critical for NIOSH to demonstrate completeness for these preceding years consistent with the objectives of its RPRT-0092 sampling plan.

1.3 Overall

In its most recent response (NIOSH, 2020a), NIOSH emphasizes the "ample" amount of routine and special bioassay data for subcontractors, particularly those in the NIOSH Division of Compensation Analysis and Support Claims Tracking System (NOCTS) claimant database, but still cannot demonstrate data completeness for subcontractor job-specific bioassays, at least for

1972–1990, that was the fundamental purpose of the RPRT-0092 analysis. SC&A does not dispute the amount of overall SRS bioassay data available, nor the programmatic strength of the routine internal monitoring program. However, attributing WSRC era practices for job-specific bioassay performance during the DuPont operating era is without basis and undercuts the premise by which the RPRT-0092 review was to ascertain the completeness of those bioassays for subcontractors. Without demonstrating that these data are complete for this category of workers for 1972–1990, NIOSH's co-exposure guidelines cannot be satisfied.

NIOSH's statement, in its recent review (NIOSH, 2020c) of SC&A's response to ORAUT-RPRT-0091 (SC&A, 2020), that a "small amount of missing routine or job-specific bioassay samples did not invalidate the radiation protection program at SRS and do not automatically invalidate the vast amounts of available monitoring data to generate a coworker model" (NIOSH, 2020c, p. 3), misses the point of the RPRT-0092 analysis. As pointed out in SC&A's (2017a) review, subcontractors are not merely another worker category. They were often transient, performed a variety of work across the site, and were often assigned higher exposure jobs, making it imperative to demonstrate that their bioassay intake data are sufficiently complete and bounded by the co-exposure model.[2] It remains unknown to what extent job-specific bioassays are incomplete, but it *is* known that the gap in 1997 was significant. SC&A concludes that the weight of evidence provided by SC&A's review of RPRT-0092 invalidates the inclusion of those data as complete and representative in the SRS co-exposure model.

2 Introduction and Background

SC&A was originally tasked by the Advisory Board in 2017 to conduct a broad review of bioassay data completeness for subCTWs at SRS, resulting in its report, "Evaluation of Savannah River Site Subcontractor Bioassay Data Completeness" (SC&A, 2017a). This completeness review was undertaken in parallel with a NIOSH effort to review the completeness of bioassay data for building 773-A for the years 1981–1986 (ORAUT-RPRT-0083, revision 00 (NIOSH, 2017a)). At the time, the Advisory Board was concerned that NIOSH's review would be too narrow (in terms of facility scope and timeframe) to resolve the issue of subCTW bioassay data completeness on a sitewide basis (ABRWH, 2016a, p. 49; 2016b, pp. 150–172).

[2] The issue of whether subCTW plutonium bioassay data exhibited higher excretion rates and derived intakes than other DuPont worker categories (specifically, DuPont CTWs and non-CTWs), was discussed at the Advisory Board's SRS work group meetings in November and December 2017. From that discussion, NIOSH provided a refined assessment based on NOCTS, supplemented by laboratory logbook bioassay data, and concluded:

> the geometric mean (GM) of the results for the DuPont CTWs are higher than that for the subcontractor CTWs for all years evaluated. For the 1973 through 1978 period, the 95th percentile intake results for the DuPont CTWs are higher as well. For the 1979 through 1987 period, the subcontractor CTWs do have a higher 95th percentile due to the higher geometric standard deviation (GSD) of the data. [NIOSH, 2019b, p. 6].

SC&A found in its response (SC&A, 2019b, p. 14), that taken "at face value," the 2019 NIOSH refined evaluation "demonstrates that subcontract CTWs had higher estimated intakes at the 95th percentile than nonsubcontract CTWs for 1979–1987." Accordingly, based on these findings and other concerns over how the refined stratification assessment was conducted, SC&A does not agree that it has been demonstrated that subcontracted and nonsubcontracted CTWs are part of the same worker stratification for the purposes of coworker modeling and thus can be appropriately combined.

Establishing data adequacy and completeness is a prerequisite for developing and applying any co-exposure model, as is currently proposed by NIOSH in ORAUT-OTIB-0081, revision 04, for construction trade workers (CTWs), including subcontractors (NIOSH, 2019c). As noted previously, SC&A finds that the rapidly changing operational circumstances at SRS beginning in the late 1980s and extending into the 1990s, with emphasis given to reactor restart, decontamination and decommissioning, waste management, and environmental cleanup, contributed to a rapid influx of subCTWs to augment onsite resources. This led to questions by SC&A and the Advisory Board about their bioassay monitoring. In particular, transient subcontractors may not have been bioassayed adequately and completely in light of their often-intermittent work on site and the lack of a comprehensive termination bioassay program. This concern was underscored by SC&A's finding that the DOE Office of Enforcement had, in fact, cited and fined WSRC in 1998 for not adequately monitoring workers performing radiation work under job-specific RWPs (DOE, 1998a). This and similar findings at other DOE sites led DOE headquarters to impose a 90-day DOE-wide moratorium on enforcement actions to allow sites to review and, as necessary, make corrections to their bioassay programs, as SRS proceeded to do in 1999 (Morgan, 1999).

In late 2017, NIOSH discovered 852 boxes of RWPs, job plans, and SWPs for SRS that encompassed the years of interest, 1972–1998. Given the paucity of RWPs identified to that point in time, these records offered a potential means to expand sampling for bioassay completeness and to characterize the subCTW cohort for the years in question. The Savannah River Site Work Group requested that NIOSH conduct such an evaluation, based on its experience evaluating bioassay completeness for building 773-A for 1981–1986 in ORAUT-RPRT-0083 (NIOSH, 2017a). The resulting subCTW completeness evaluation is documented in RPRT-0092.

To guide that evaluation, NIOSH prepared an "SRS Work Permit Sampling Plan" that had as its primary goal to "randomly select radiological workers from various areas at the Savannah River Site (SRS), such that an evaluation of monitored and unmonitored workers can be conducted" (NIOSH, 2018a, p. 1). NIOSH noted in its transmittal of the plan that

> The attached SRS Work Permit Sampling plan describes what we have learned and proposes details of how information can be sampled to obtain an unbiased data set to evaluate subcontractor monitoring for both co-worker applicability (original question – did monitored and unmonitored subcontractor CTWs work together) and to evaluate specific radionuclides of interest (new question – appropriate source term). [Taulbee, 2018]

This sampling plan provided the original premise for and approach to the bioassay data completeness review in RPRT-0092.

In an earlier presentation to the SRS work group (NIOSH, 2017b), NIOSH found that 91 percent of 371 subcontractor claimants in NOCTS (340 of 371) have internal monitoring data. Based on a qualitative review, NIOSH observed that any lack of monitoring appeared to be "randomly distributed." However, as emphasized before the Advisory Board in 2017, SC&A believes that the key question that remains is the representativeness of those data. As concluded by SC&A at that time (2017b):

- "Representativeness" is a key issue: How relatable are exposures of subcontractors on RWP job-specific bioassays compared to those working under "typical" or general work conditions with prescheduled routine bioassays? NIOSH needs to adequately demonstrate that routinely monitored workers were doing the same jobs or tasks as those solely on job-specific bioassay.

- RWPs before 1999 at SRS were neither complete nor consistently applied with respect to job-specific bioassays. Unmonitored intakes may have occurred due to workplace radiological source terms not being properly characterized and included in RWPs. Most RWPs appear to be missing for WSRC 1989–1995;[3] few remain for the DuPont era (past interviews indicate subcontractor records destruction in 1989 during contract transfer).

SC&A's approach to reviewing RPRT-0092 is distinguished by the two time periods and two corresponding SRS operating contractors—DuPont and Westinghouse—who programmatically defined and implemented distinctly different work permit and job-specific bioassay programs for 1972–1989 and 1990–1998, respectively.[4] This distinction manifested itself in a number of ways but was most apparent in the lack of procedural requirements, permit records, job-specific bioassays, and other program documentation before 1990, with major initiatives thereafter by WSRC to update requirements, define formal technical bases and procedures for internal dosimetry, and hold line management and workers more accountable for adhering to them.

The lack of available records led NIOSH to diverge from its sampling plan for the 1972–1989 (DuPont) period and collect all applicable permit records, which happened to be for only one area, 773-A/776-A, SRS's analytic laboratory operation. SC&A divided its review in a similar manner, focusing first on the premise and assumptions underpinning NIOSH's evaluation for each of the two time periods (DuPont vs. WSRC), with a second assessment of how the sampling was actually performed for plutonium, americium, and fission products consistent with the sampling plan goals and evaluation objectives.

For RPRT-0092, NIOSH noted that the "chief conclusion of [its] report is that a large percentage of subCTWs were monitored for potential intakes while working under a Job Plan, SWP or RWP" (NIOSH, 2019a, p. 59). Several key findings supported this conclusion:

- "When considering subCTWs identified from Job Plans, SWPs, and RWPs from 1972 through 1998 as a combined unit of time, 1,271 (89%) of the 1,389 subCTWs were monitored for at least one radionuclide" (p. 59).

[3] The records discovered at the Atlanta Records Center in late 2017 included numbers of RWPs for the WSRC era, making it more feasible to demonstrate the completeness of subCTW job-specific bioassays required by those RWPs.

[4] Again, the continued lack of RWPs and job-specific bioassays in 1990 would make that year's job-specific bioassay program performance more like the previous DuPont era than that of the later Westinghouse bioassay program.

- "Effective rates[5] of monitoring are consistent across the three sets of data used for the combined 1972 to 1998 period . . . averaging 97%" (p. 59).

- The effective monitoring rate of subCTWs for 1972–1974 was 51 percent for plutonium, with 74 percent having had fission product samples. For 1980–1989, 76 percent of subCTWs were monitored for americium, and 99 percent were monitored for plutonium.

- Bioassay data from subCTWs who were contaminated while working in F and H Areas show over 90 percent of subCTWs were monitored for required plutonium bioassay and over 80 percent were monitored for required fission product bioassay. The data show no appreciable difference in the rate of monitoring across crafts or SRS areas.

Notwithstanding NIOSH's conclusion that overall, "a large percentage of subCTWs were monitored," SC&A focused on the central question of the RPRT-0092 analysis: whether the completeness of subCTW permit-indicated, job-specific bioassays can be demonstrated. SC&A's goal was to test both the central thesis for RPRT-0092—that bioassays can be linked to corresponding work permits so that monitored subCTWs can be compared with unmonitored subCTWs—and whether the actual sampling process was conducted in a sound manner. As such, it is a weight-of-evidence assessment that reviews all aspects of NIOSH's evaluation in RPRT-0092, from sampling premise and design, to sampling execution, and finally, to results achieved. If NIOSH's analysis is incomplete, by virtue of bioassays that cannot be related to individual subCTWs and their jobs, source-terms that are not necessarily representative of actual operations, and facility sampling that is not representative of SRS-wide radiological operations, the results above would not be valid as a measure of data completeness.

Furthermore, a central question is whether co-exposure intakes developed in ORAUT-OTIB-0081 adequately represent the exposure potential experienced by unmonitored subCTWs. Representation is a core tenet in co-exposure modeling, as defined in DCAS-IG-006, rev. 0, "Criteria for the Evaluation and Use of Co-Exposure Datasets" (NIOSH, 2020b).

3 SC&A Response: Assumptions and Basis for Subcontractor Data Sampling, 1972–1990

3.1 SC&A finding 1

> No SWPs or job plans sampled by NIOSH for 1972–1990 contain any requirements or indications for job-specific bioassays, despite respiratory protection being required, bringing into question the approach taken to satisfy RPRT-0092's first evaluation objective. [SC&A, 2019a, p. 12]

3.1.1 SC&A summary of NIOSH response

NIOSH contends that even though it agrees that bioassays were neither checked nor entered on work permits or job plans, it can rely on the "ample" number of bioassays whose dates can be "associated" with these permits and job plans, with the assumption that bioassays would have

[5] "Effective rate" is defined by NIOSH as the number monitored plus those unmonitored that had a coworker that was monitored.

been obtained. For various time periods during the DuPont era (1972–1989), except for 1975–1979 (where SWPs or job plans could not be found), NIOSH points to the WSRC-era Farrell and Findley (1999) report and DuPont procedural requirements as a period-specific basis for assuming (1) bioassay control procedures were being implemented in 773-A and (2) fission product, americium, and plutonium bioassays were being taken for subCTWs.

3.1.2 SC&A response

NIOSH's response to SC&A's finding essentially retreats from its original sampling approach for the RPRT-0092 bioassay survey, which was intended to identify and relate job-specific bioassays based on permit or job-plan indicated monitoring for individual subCTWs. Where such monitoring was not explicitly indicated (as for job plans), NIOSH planned to use indicated respiratory protection as a secondary marker with the assumption that by contemporary standards, workers would have been on a bioassay[6] (ABRWH, 2019, p. 20). The original objective was to demonstrate the completeness of job-specific bioassays for the SEC years in question (1972–1998) by linking SWPs and job plans with their respectively required bioassays for the DuPont era (1972–1989/1990), and by similarly linking RWPs with required bioassays for the WSRC era (1991–1998). These linkages have not been substantiated for 1972–1990 by the analysis presented in RPRT-0092, as documented in SC&A's (2019a) review, which reviewed all of the sampled job plans and SWPs for that purpose.[7]

Instead, in the face of SC&A's finding of few relatable job-specific bioassays based on permit indicators for the DuPont era, NIOSH (2020a, p. 4) now contends it nonetheless has an "ample number of bioassays" that have dates that can be "associated"[8] with a permit or job plan. NIOSH also assumes that bioassays "would have been obtained" based on era-related program procedures.

Without any measure of actual subCTW and CTW worker bioassay conformance with job plan or SWP bioassay requirements, how does NIOSH speak to subCTW data completeness or job-specific bioassay program implementation? A large or "ample" number of bioassay results, by itself, does not have meaning in this context and would have been available to NIOSH from the start, in any case, without the analysis that RPRT-0092 was originally intended to accomplish. Likewise, how can NIOSH assume that bioassays would have been taken, when an accountable RWP program was not in place before the early 1990s, general DPSOL procedures were interpreted and not necessarily applied consistently by individual facility managers, and it was

[6] NIOSH clarified at the December 2019 work group meeting that such bioassays would include all bioassays, including both prescheduled routine ones and nonroutine job-specific bioassays.

[7] Additional RWPs for the WSRC era, 1991–1998, were found in the 852 boxes of records and served to supplement what was previously available and made such linkage more feasible, particularly after full implementation of the RWP program implement put in place by WSRC. However, completeness questions remain for the early 1990s as WSRC proceeded to implement sitewide RWP requirements and hold workers more accountable for complying with job-specific bioassays. NIOSH acknowledges that radionuclides were not specified in early RWPs until about 1994 (NIOSH, 2020a, p. 35).

[8] NIOSH's use of "associated" in this case appears to be based on subcontractor workers working on the same permit, but not necessarily on the same dates. From a limited sampling of plutonium bioassay data for 1990–1998 (given the availability of RWPs with linked job-specific bioassays during the WSRC era), SC&A found that 25 percent (12 of 48) of RWP sign-in dates did not match, with some off by a day or up to several weeks (refer to observation 4).

found by DOE's Tiger Team in 1990 that SRS management did not hold workers and supervisors accountable for bioassay submission?

This is not an acceptable resolution to the issue at hand. It does not satisfy established Advisory Board concerns over whether the incompleteness of job-specific bioassays identified in 1997 can be addressed for preceding years by the sampling of permits and job plans that was intended for RPRT-0092. It does not accomplish the central goal of the NIOSH sampling plan by which individual SWPs, job plans, and RWPs were to be surveyed for the completeness of their accompanying job-specific bioassays, and whether exposures of subcontractors on job-specific bioassays compared well to those working under "typical" or general work conditions with prescheduled routine bioassays.

In its 2019 response, SC&A (2019a) established the following for the DuPont era (1972–1989/1990):

1. Lack of actual linkage between SWPs and job plans (and even respiratory protection) and required followup bioassays – No evidence was found of job-specific bioassays being performed in response to SWPs or job plans.

2. Lack of SRS operational representativeness – Only building 773-A job plans and SWPs were found for 1972–1974 and 1980–1989, and none were found for 1975–1979.

3. Lack of procedural requirements or documented practice that required job-specific bioassays based on either SWPs or job plans, or respiratory protection – NIOSH already concluded that DPSOP (or DPSOL) procedures under DuPont were too "general" to be a basis for identifying permit-related, job-specific bioassays.

4. The back application of the Farrell and Findley (1999) source characterization criteria to identify relevant radionuclide source terms for DuPont era operations of 1972–1989 is not supported, given the widely varying radioactive materials being handled in earlier years and the lack of a routine, comprehensive characterization process available at that time (addressed in more detail in SC&A's (2019a) report and summarized in section 3.3.2).

Without a means to demonstrate the completeness of SWP or job plan-based bioassays during the DuPont era, coupled with the lack of procedural requirements for such bioassays and lack of an implemented RWP program with comprehensive source characterization, SC&A continues to find that NIOSH has yet to demonstrate the completeness of bioassay data for subCTWs for 1972–1990, and perhaps into the early 1990s. Therefore, a co-exposure model satisfying the tenets of DCAS-IG-006 would not be feasible for that worker category for that timeframe.

3.2 SC&A finding 2

> "Radionuclides of interest" assumed for sampled permits in RPRT-0092 are of questionable accuracy given cited lack of adequate radiological source term characterization prior to 1990. [SC&A, 2019a, p. 12]

3.2.1 SC&A Summary of NIOSH response

NIOSH contends that prior to 1990, the radiological source terms for SRS facilities and operations were adequately characterized by the "multiple ways" available to DuPont to have done so, and cites documented examples. These include (1) isotope production and inventory records, e.g., for special nuclear materials (plutonium, enriched uranium); (2) specific work-based characterizations performed of routine and nonroutine work; (3) routine reporting of radionuclide material production and use data in the monthly Works Technical Reports; (4) records of contamination incidents that cite specific radionuclides involved; and (5) DPSOL requirements for radionuclide bioassay type and frequency determination, including specifications for certain SRS facilities.

3.2.2 SC&A response

It is unlikely that facility "radionuclides of interest" for bioassay purposes were accurate and updated for changes in operations or experience during the DuPont era, regardless of the various characterization activities cited by NIOSH. These activities may or may not have identified relevant source term information, which may or may not have then been applied to exposure source-term identification for SWPs and job plans. General DPSOL-based job plans and bioassay requirements, coupled with delegated implementation of those requirements through SRS facility managers, would have made consistent radiological characterization and accurate radionuclide identification difficult. The DOE headquarters-led Tiger Team review of 1990, supported by outside (non-SRS) health physics professionals, made this programmatic shortcoming abundantly clear:

> The internal dosimetry program does not comply with the requirements of DOE 5480.11. **Radiological areas have not been sufficiently characterized to provide a technical basis for the assignment of bioassay sample types and frequencies.** [DOE, 1990, p. 4-193]. [Emphasis added.]

DOE detailed the basis for its finding as follows:

- The technical basis for determining bioassay type and frequency has not been established for the nuclides encountered at SRS. The Naval Fuel Facility was characterized (report dated February 16, 1989) to provide a basis for assigning the proper bioassay type and frequency to workers in that facility. However, **no other nuclear facilities have been characterized in a similar manner**. Consequently, bioassay assignments are made without the benefit of a sound technical basis. Health Protection (HP) Operations Managers decide the type and frequency of routine bioassays, based on DPSOP 193-211, Table A.

- Particle size and solubility are not well known or used to help decide bioassay type and frequency. [DOE, 1990, p. 4-198] [Emphasis added.]

In its June 20, 1990, action plan response, WSRC agreed that "a formal technical basis for the SRS bioassay program has not yet been established" but emphasized that its program was "based on years of experience [and an] awareness of what has constituted good practice in the past, common sense, and conservative assumptions for determining employee doses" (WSRC, 1990a,

PDF p. 432). It further noted that SRS was in the process of developing a technical basis document for the internal dosimetry program that would be "consistent with the requirements of the Order [5480.11] and appropriate guidance." The action plan further detailed that, "**during the development of the technical basis manual this year, the radionuclide materials at each area on the site are being characterized**" (WSRC, 1990a, PDF p. 432; emphasis added), which would have constituted the first sitewide facility-by-facility radiological characterization.

This rapid evolution of facility radiological source term characterization approach during the late 1980s to early 1990s is corroborated by Tom LaBone, the WSRC manager of Internal Dosimetry at the time, who responded to the following question (LaBone, 2017):

> **Question 18**
>
> . . .To what extent did this deficient RWP source term review process [for americium-241 (Am-241), as detailed in a 1999 WSRC document, "Response to the Compilation of PAAA Internal Dosimetry Issues (U)"] extend to job-specific RWPs and in the larger sense, how much broader was this issue (improper bioassay enrollment) in terms of other radionuclide source terms on a site-wide basis in prior years (e.g., 1989–1999)? Did WSRC review prior RWPs to ascertain status on this question, or to address potential missed dose from americium and other radionuclides due to inadequate enrollment reviews?
>
> **Response 18** [partial]
>
> I think that when SRS moved from the production phase to the D&D phase in the 1990's there were changes in the source terms that were not fully anticipated because of the change in mission. This, combined with a change in the way we specified routine bioassay programs was most likely the cause of the problem with the routine program you cited with Am-241.

As noted in SC&A's (2018) review of "Missing or Incomplete Radiological Source Terms," "the implication of what was provided in this interview was to substantiate that the disparities with source term identification had its roots in the rapidly changing nature of SRS' mission, with new or more complex source terms not being fully anticipated as the site moved from a primary production mission to one that included D&D, as well as how routine bioassay programs were implemented" (p. 5). In its October 2, 2020, memorandum on this issue, NIOSH agrees that "although large-scale D&D operations did not start until after 1999, NIOSH acknowledges that during the mid-1980s through the late-1990s operations began to change from production to D&D, environmental cleanup and waste management activities" (NIOSH, 2020c, p. 3).

A sitewide workplace characterization process was implemented as part of an overall SRS Radiological Improvement Plan in the early 1990s, and WSRC manual 5Q1.1 provided strengthened accountability among facility managers. However, a 1999 WSRC self-assessment following the 1998 enforcement actions, which focused on significant lapses in implementation of the WSRC job-specific bioassay program, established that for two SRS facilities, Am-241 was identified as a potential operational source term but not included in the routine bioassay program. A contributing root cause for this discrepancy was found to be an apparent carryover of DuPont

era facility managers and health protection organizations who continued to rely on their longstanding radionuclide type and frequency tables and their personal knowledge of facility operations. WSRC subsequently developed an updated methodology (Farrell and Findley, 1999) that provided a detailed, facility-by-facility baselining of relevant radiological source terms based on a review of "existing waste certification or process stream analysis data" (Farrell & Findley, 1999, p. 2). As emphasized in the Farrell and Findley (1999) guidance, a comprehensive and data-driven process is necessary for the following reasons:

> **certain facilities such as the Savannah River Technology Center (SRTC) [building 773-A] and the solid waste disposal facilities handle a wide array of radioactive materials, some of which may not be encountered in the typical radiological work environment by workers in those areas**. For facilities such as 221-FB-Line, where the source term is well defined and not subject to change, this is not a concern unless there is a major change in the facility mission. To ensure that the proper radionuclide(s) is identified for the RWP urine sampling program it may be necessary to perform a thorough characterization of the work environment. It is important also that this characterization be performed on a routine basis to stay current on the source term present. [WSRC, 1998, p. 2] [Emphasis added.]

NIOSH's citing of available characterization means by which DuPont could have done so (i.e., could have exercised the capability to identify radionuclides from inventory, incident and specific job activities, and DuPont procedures) belies the finding that the source term characterization process during the DuPont era, prior to DOE-directed corrective action in 1990, was neither systematic, comprehensive, or performed on a routine basis, as determined by the independent health physics assessment conducted as part of the DOE headquarters review. That status and condition is even acknowledged in the further WSRC upgrades cited in Farrell and Findley (1999).[9] Even if an RWP program had been implemented during the DuPont era,[10] it would not necessarily have been based on accurate or representative source terms. This is even less so, then, for the job plans relied upon and interpreted by individual SRS facility managers to apply what were generalized DPSOL tables and procedures for radionuclide type and frequency.

NIOSH's response, contained in its recent review of SC&A's response to ORAUT-RPRT-0091 (NIOSH, 2020c, p. 3), that a "small amount of missing routine or job-specific bioassay samples did not invalidate the radiation protection program at SRS and do not automatically invalidate the vast amounts of available monitoring data to generate a coworker model," misses the point

[9] NIOSH raised the possibility of a comparative analysis of known DuPont era facility source terms with those postulated by Farrell and Findley (1999) as a means of validation (ABRWH, 2019). However, as acknowledged in the Farrell and Findley (1999) guidance and WSRC (1998), a wide array of radionuclides were handled in some SRS facilities, such as 773-A and waste management operations, which would make it difficult, if unlikely, to ascertain what specific radiological source terms may have had exposure potential for individual jobs over the years given the lack of specificity in DuPont era facility records.

[10] The RWP program was discontinued in the 1960s by DuPont in favor of applying internal DPSOL procedures, but as a DOE assessment pointed out, a requirement for RWPs and Standing Radiological Work Permits for any work within a radiologically controlled area was carried forward as cited in Special Hazards Bulletins in DPSOP 40, revision 82, September 1989. As DOE observed, "Radiation Work Permits or Standing Radiation Work Permits are not used even though required by Westinghouse Savannah River Company procedures and accepted industry standards" (DOE, 1990, p. 4-307).

about the adequacy of source term characterization and its implications for worker enrollment, particularly as it pertains to permit-indicated job-specific bioassays. NIOSH may believe that "prior to 1990, the radiological source terms at SRS were adequately characterized" and that the "significant amount of workplace and individual [bioassay] monitoring" obviates any shortcomings in their completeness (NIOSH, 2020c, p. 2). However, for at least the DuPont operating era, this supposition does not stand up to the lack of any evidence of consistent, analysis-based radiological source-term characterization based on DPSOL procedures, actual job plans or SWPs sampled, and independent audits of program performance.

SC&A stands by its finding that the "'radionuclides of interest' assumed for sampled permits in RPRT-0092 are of questionable accuracy" for the DuPont era. SC&A also finds that because of their apparent incompleteness, NIOSH is unable to ascertain whether appropriate job-specific bioassays were (a) performed in response to indicated job plans or SWPs or (b) in response to indicated respiratory requirements. Without a substantiated basis for linking its surveyed job plans and SWPs with appropriate radionuclide-specific bioassays, NIOSH would be unable to accomplish that fundamental sampling objective of RPRT-0092's survey and adequately demonstrate subCTW bioassay data completeness.

3.3 SC&A finding 3

> The scope of permit sampling for 1972–1990 at SRS is essentially limited to one facility, 773-A, falling short of achieving NIOSH's sampling objective and the representativeness called for in NIOSH's coworker [co-exposure] guidelines. [SC&A, 2019a, p. 12]

3.3.1 SC&A Summary of NIOSH response

NIOSH contends that subCTWs were adequately monitored in areas outside 773-A between 1972 and 1990. This argument is premised on CTWs being monitored for radionuclide intakes based on the radionuclides of interest in a similar manner as prime contractor workers. It is based on (1) a review of available plutonium logbooks to enumerate the total subCTWs sampled for plutonium by year and their facility location and (2) the number of subCTWs having plutonium and fission product urinalyses and whole-body counts, by year, based on ORAUT-RPRT-0094 (NIOSH, 2019d). NIOSH indicates that these additional coding efforts support the representativeness called for in the co-exposure implementation guide.

3.3.2 SC&A response

As stressed in its 2019 RPRT-0092 review, SC&A (2019a) disagrees that CTWs were necessarily "monitored for radionuclide intakes based on the radionuclides of interest in a similar manner as prime contractor workers" (NIOSH, 2020a, p. 7) during the DuPont era (1972–1989/1990). As noted in SC&A's report:

> DPSOL procedures for bioassay . . . provided different guidelines for construction workers versus operational workers. Operational workers had type and frequency of bioassay sampling designated by specific area and facility, while construction workers had general requirements, with discretion provided facility managers or local health physics to specify bioassay for job-specific radionuclides. The only site-wide requirement was for plutonium, tritium, and fission products, with all

> other radionuclides to be addressed in construction job plans (DuPont, 1971). However, there is no evidence in the sampled permits referenced in RPRT-0092 for 1972–1989 of any such sampling for "other radionuclides" being required in job plans for CTWs or subCTWs. Without [nonroutine[11]] job-specific bioassays to complement the required plutonium, tritium and fission product routine bioassays, "roving" construction workers would not have been adequately enrolled for the radionuclides to which they may have been potentially exposed, and the bioassay database for both CTWs and subCTWs would accordingly be incomplete. [SC&A, 2019a, p. 21]

As noted in the preceding passage, the availability of subCTW bioassay data for plutonium and fission products for SRS locations other than 773-A is not surprising, given that sitewide routine bioassay monitoring was only specified for plutonium, tritium, and fission products. However, the inability to produce *permit-based* bioassay sampling records for any radionuclides during the period 1972–1990 for the other 30+ radiological facilities at SRS negates NIOSH's ability to demonstrate bioassay data completeness for subCTWs during the DuPont era (i.e., prior to WSRC-inaugurated sitewide facility source term characterization and RWP implementation). As listed by SC&A (2019a), there is a wide range of facility source terms that have figured in historic operations at SRS including uranium-235 (U-235), U-238, and neptunium-237, in addition to plutonium, mixed fission products, and tritium. For operations such as those in 773-A (Savannah River Laboratory), as noted previously in section 3.2.2, a wide array of radioactive materials were handled that were neither routine nor found in other SRS facilities. And even for 773-A, NIOSH is unable to connect job-specific bioassays with the actual SWPs or job plans that would have required them.

NIOSH's evaluation of NOCTS data in ORAUT-RPRT-0094 indicates that 20 to 77 percent of the subcontractors who are claimants working in 1972–1989 have some form of internal monitoring data, in vitro and/or in vivo (NIOSH, 2019d, p. 14, table 5-2). (It should be noted that this is substantially less that the 71 to 94 percent of the subcontractors bioassayed for the period 1990–1998.) However, as emphasized earlier in section 3.1.1, this is not the issue. The representativeness called for in NIOSH's co-exposure guidelines, which was a key basis of the intended sampling to be performed for RPRT-0092, remains unresolved because the overall percentage of workers bioassayed does not address the degree to which subCTWs were monitored for permit-indicated radionuclides via job-specific bioassays and whether those radionuclide source terms were appropriate.

SC&A stands by its finding that the NIOSH survey in RPRT-0092 (1) does not satisfy its objective of sampling from "various areas" at SRS and (2) despite the addition of a substantial additional set of records (852 boxes), can still only base its determination of bioassay data completeness for the DuPont era on data from one facility, 773-A. (The inclusion of incident-based data for F and H Areas is addressed separately below, in section 3.4.2.) NIOSH's citation of sitewide subCTW bioassay data for plutonium and fission products, and for RPRT-0092 claimant subCTW bioassay data, does not change this conclusion for the reasons stated. Such

[11] Job-specific bioassays were defined as nonroutine bioassays until the mid-1990s, when they were redefined in the WSRC 5Q1.1 procedure and incorporated into the routine program as part of internal exposure verification. They were defined as part of the routine bioassay program in the internal dosimetry technical basis manual beginning in 1991.

data presumably encompass both routine and nonroutine (i.e., job-specific) bioassays. Such a limited scope of subCTW data review, and one that does not address its representativeness or completeness, does not satisfy the tenets of DCAS-IG-006 criteria for the evaluation and use of co-exposure datasets (NIOSH, 2020b).

3.4 SC&A finding 4

> SRS incident-based/special bioassays were provided by workers on a more stringent procedural basis and should not be used to supplement the evaluation of permit-related, job-specific bioassays for 1972–1989 as a measure of historic data completeness. [SC&A, 2019a, p. 12]

3.4.1 SC&A summary of NIOSH response

NIOSH contends that incident-based/special bioassay sampling was an integral component of the SRS bioassay program for both prime and subcontractor workers and cannot be disconnected from the routine monitoring program. Some limited validation of incident-based/special bioassays in the F and A Areas was performed, which found "a high measure of completeness" and "no systemic program issue" (NIOSH, 2020a, p. 10). NIOSH further cites its "*Criteria for the Evaluation and Use of Coworker Datasets*" (NIOSH, 2020a, p. 10) as permitting its use as a basis for co-exposure modeling of unmonitored workers. NIOSH points out that the inclusion of the incident-based bioassay data was "not meant to complement completeness of the non-incident/non-special bioassay data," and that such data will be more bounding and bias the co-exposure model higher (NIOSH, 2020a, p. 10).

3.4.2 SC&A response

SCA& agrees with NIOSH's response, insofar as it applies to bioassay data supporting co-exposure modeling, but points out that the context of SC&A's finding is the important distinction in this case. In the specific context of the RPRT-0092 survey of subCTW job-specific bioassay completeness, SC&A finds that incident or intake-driven "special bioassays" were not procedurally required in the same manner as job-specific bioassays. While special bioassays were prescribed in response to an incident, as follow-up to a known intake, or positive routine bioassay and embodied a rigorous management accountability process, job-specific bioassays during the DuPont era were conducted based on general DPSOL guidance that individual facility managers interpreted and applied with little apparent consistency and management accountability. Accordingly, the "completeness" of bioassay data for the special bioassay program would undoubtedly (and, in fact, was shown to) be consistently high, while the same cannot be said for job-specific bioassays, for which the issue of accountability and completeness was raised by DOE's Tiger Team assessment in 1990. SC&A considers mixing the results together of both programs in RPRT-0092 to be potentially misleading and would unduly enhance the apparent completeness of the actual SRS subCTW job-specific bioassay program beyond the very limited and indeterminate results found by NIOSH in RPRT-0092 for 773-A. NIOSH seems to agree, given its statement that the inclusion of these data was "not meant to complement completeness of the non-incident/non-special bioassay data" (NIOSH, 2020a, p. 10).

Notwithstanding this admission, the finding presented in RPRT-0092 does not support this now clarified intent. NIOSH noted in RPRT-0092 that while it did not capture job-specific data for areas other than 773-A, it did capture incident data for F and H Areas from which it identified 45

subCTWs who received contamination for which special bioassays would have been performed. Based on individual bioassays performed for these reported incidents, NIOSH concluded that "monitoring rates [i.e., completeness, as provided in RPRT-0092, table 5-14] for plutonium bioassay compare favorably to rates given for the same monitoring in Table 5-7 for subCTWs working in Building 773-A" (NIOSH, 2019a, p. 56). If NIOSH's did not mean to "complement" its assessment of subCTW job-specific bioassay data completeness in RPRT-0092 using such incident-based rates, this conclusion should be reframed or otherwise corrected.

SC&A stands by its original finding but accepts NIOSH's most recent response as concurring that such incident-based bioassay completeness data should not be used to complement the completeness survey of permit-indicated, job-specific bioassays provided in RPRT-0092.

3.5 SC&A finding 5

> The incompleteness of SRS dose records for 1972–1990 is substantiated by the acknowledged destruction of subcontractor records and firsthand worker accounts, coupled with DOE findings of missing occupational radiation dose data from many SRS personnel files, as well as systemic bioassay delinquencies, and wide gaps in NIOSH's capture of permit documentation. [SC&A, 2019a, p. 12]

3.5.1 SC&A summary of NIOSH response

NIOSH "does not agree that dosimetry records for workers were destroyed or lost, but rather, were stored offsite in approved permanent storage facilities [WSRC 1990a, PDF p. 439]." NIOSH finds that "the first part of Finding 5, 'The incompleteness of SRS dose records for 1972–1990 is substantiated by the acknowledged destruction of subcontractor records and firsthand worker accounts…' is a misleading statement," and notes that "it implies that subcontractor records, including dosimetry records, were destroyed" (NIOSH, 2020a, p. 11).

NIOSH further finds that "the second part of Finding 5, '…DOE findings of missing occupational radiation dose data from many SRS personnel files…' is misleading" (p. 11) and notes what it believes are inconsistencies in SC&A's statement's regarding the availability of records stored at the Federal Repository in Atlanta, Georgia. NIOSH finally observes that the wide gaps in NIOSH's capture of permit documentation cited by SC&A exists because of some of the issues discussed in the first parts of SC&A's finding, presumably the destruction of subcontractor records. It is NIOSH's belief that "while some permit documentation is unavailable for capture at this time, doses can be reconstructed with sufficient accuracy using the existing data on hand" (NIOSH, 2020a, p. 12).

3.5.2 SC&A response

SC&A's finding, as made clear in the opening paragraph of section 4.5 of SC&A's (2019a) report, is made in the specific context of NIOSH's finding that "only one area (A Area) appears to have routinely used SWPs and/or Job Plans in the 1972 through 1989 era (DuPont era)" (NIOSH, 2019a, p. 14). SC&A disagrees with this finding because such a conclusion would be misleading given the known destruction of DuPont era subcontractor records and past problems with accessing complete records from the Federal Repository in Atlanta, GA. It is just as possible, if not probable, that other SRS areas routinely used SWPs and/or job plans in the DuPont era, but those records may simply be missing or unavailable. NIOSH appears to correct

this finding by a later statement in RPRT-0092 that "the only clear information the team was able to glean from this search is that SWP and Job Plans are **only available** for one area during the period from 1972 to 1990" (NIOSH, 2019a, p. 15; emphasis added).

SC&A continues to raise the issue of subcontractor records destruction in the context of SRS records completeness because it was not clear that NIOSH had addressed the scope and implications of this acknowledged destruction, other than to indicate that it may have occurred but that the existing data are sufficient to support dose reconstruction with sufficient accuracy.

SC&A's statement in finding 5 that "the incompleteness of SRS dose records for 1972–1990 is substantiated by the acknowledged destruction of subcontractor records and firsthand worker accounts" is based on NIOSH's own admission that "current and former employee interviews indicated that some records were destroyed in the late 1980s or early 1990s" and "the SWPs or Job Plans for other areas might have been destroyed as part of that effort" (NIOSH, 2019a, p. 15). However, as reflected in SC&A's full summary of the interviews in question, this subcontractor records destruction involved "all kinds of records," including "monitoring records" and "time cards" and took place in early 1990 following Westinghouse assuming the SRS operating contract from DuPont (SC&A, 2019a, p. 35). The reported destruction of both time cards and monitoring records for subcontractors working at SRS prior to 1990 raised the issue of whether the identity of SRS transient subcontractors and their monitoring records during the DuPont era are complete. Notwithstanding its conclusion that there are adequate dose records to support dose reconstruction, it was not apparent that NIOSH had investigated this issue further.

SC&A disagrees with NIOSH's assertion that it is "misleading" to point out that "subcontractor records, including dosimetry records, were destroyed" (NIOSH, 2020a, p. 11). While SC&A did, indeed, indicate that subcontractor records were reported destroyed (as did NIOSH), SC&A cited interviewees reporting that monitoring records and timecards were among the records destroyed. It is unclear what such "monitoring records" would have included, but if those did include dosimetry records, that would need to be investigated and, if confirmed, addressed further, as has been done at other Energy Employees Occupational Illness Compensation Program Act (EEOICPA) sites.

SC&A's reference to "DOE findings of missing occupational radiation dose data from many SRS personnel files" is based on a formal finding by the DOE headquarters Tiger Team in early 1990:

> Comprehensive records related to occupational radiation exposure are not retained consistent with ANSI N13.6. There are many personnel files where radiation dose data are missing for many years. [DOE, 1990, p. 4-193, PDF p. 530]

DOE found that SRS radiation records did not satisfy the Department's performance requirement that "records related to occupational exposure should accurately document exposure received and be readily retrievable" (DOE, 1990, p. 4-202, PDF p. 539).

The contradiction that NIOSH contends to exist between SC&A's recitation of these 1990 DOE findings and NIOSH's contemporary ability to access records from the Federal Records Center is not apparent. DOE's inability to locate recorded radiation dose data "for many years" for SRS

personnel may or may not have been related to retention or unavailability from the repository; it is simply a statement of fact that a sampling of records reviewed by DOE showed substantial gaps in radiation dose data.

However, SC&A accepts NIOSH's explanation that "all the dosimetry data was retrieved by SRS in 2001 in order to prepare and respond to [EEOICPA]" and that through a thorough process of records retrieval and indexing, a data set suitable for dose reconstruction was compiled (NIOSH, 2020a, p. 12). Coupled with NIOSH's verification process based on claimant data in the NOCTS database, SC&A acknowledges that NIOSH has confirmed that there is no evidence to date of dosimetry data gaps that may have stemmed from the reported subcontractor records destruction in 1990.

On a separate question in its response to SC&A's finding of "systemic bioassay delinquencies," NIOSH "does agree that there were some delinquencies" but believes it does "not impede NIOSH's ability to demonstrate completeness for most of the radionuclides of interest during the DuPont era (1972–1989)" (NIOSH, 2020a, p. 12). Of course, this question of systemic bioassay delinquencies is at the root of NIOSH's RPRT-0092 survey of job-specific bioassay completeness and is addressed in toto by SC&A's review. The issue is not whether such "delinquencies" existed; they did. The issue is the *degree* to which they existed and, by an analysis of the resulting permit-indicated, job-specific bioassays as RPRT-0092 was to provide, whether subCTW job-specific bioassays could be demonstrated as being sufficiently complete for SRS co-exposure model development. Also, of course, a question remains as to whether completeness of "most" but not all of the radionuclides of interest at SRS is sufficient for dose reconstruction with sufficient accuracy.

3.6 SC&A observation 1

> The back application of assumptions regarding work permits, job-specific bioassays, and target radionuclides to conduct a completeness review for 1972–1998 is not plausible given the significant changes in radiological policies, procedures, and practices that occurred in the early 1990s. [SC&A, 2019a, p. 13]

3.6.1 SC&A summary of NIOSH response

"NIOSH does not agree with the premise that significant changes in radiological policies, procedures, and practices that occurred in the early 1990s preclude the ability to conduct a completeness analysis during the 1972–1998 evaluation period. . . . despite the changes made from DOE Order 5480.1, Chapter XI (issued 5/5/80, effective as 5480.1A 8/13/1981) to DOE Order 5480.11 (issued Dec. 1988, effective Dec. 1989), SRS policies, procedures, practices, and the required types and locations for routine bioassay analyses remained largely constant between 1972 and 1998" (NIOSH, 2020a, pp. 23–24). As its basis, NIOSH goes on to specify and describe the various radiological control programs, specifically routine and special bioassay monitoring programs, that were implemented during this continuous time period.

3.6.2 SC&A response

SC&A finds questionable NIOSH's assertion that significant changes in radiological policies, procedures, and practices that occurred in the early 1990s at SRS do not preclude a common-based completeness analysis, as performed in RPRT-0092, for the overall 1972–1998 period. As

illustrated by the analysis in RPRT-0092, a completeness review can be conducted over this lengthy operational time frame, but only if based on the premise of later (WSRC) radiological practices being assumed and back-applied as a constant for the entire 25-year period. While NIOSH's claim is founded on the consistent application, over time, of SRS routine and special bioassay programs, it is the *nonroutine* job-specific bioassay program that is in question. In this context, SC&A finds NIOSH's response and this approach to be without basis for a number of the key elements that constitute NIOSH's sampling and analysis regime in RPRT-0092. These points were detailed in SC&A's (2019a) review but are summarized below.

First, the RPRT-0092 completeness analysis assumes that SWPs of the DuPont era (1972–1989/1990) specify job-specific bioassays to be performed or, in the case of job plans, respiratory protection is assumed to require them. However, while bioassay checkoffs were provided on SWPs and DPSOLs provide for such bioassays for job plans, *none* were checked in NIOSH's sampling, and there is no evidence of linkage between the permit (or plan) and such bioassays. Required job-specific bioassays as part of a work permit were not implemented until WSRC became the operational contractor in the early 1990s and RWPs were implemented. Apart from the lack of clear requirements, DuPont and early WSRC management did not necessarily hold workers accountable to providing bioassay samples, as found by DOE in its 1990 Tiger Team assessment:

> Employees who fail to leave a scheduled bioassay sample for over 1 month are added to a delinquent list. The list also tabulates those who are 2, 3, and 4 months delinquent. A person who is 5 months delinquent is listed again as being 1 month delinquent. There is a policy to remove people from radiation work if they are 3 months delinquent on a bioassay sample. However, there is no enforcement of this policy and some employees ignore requests for bioassay samples. [DOE, 1990, p. 4-198, PDF p. 535]

DOE concluded that "when scheduled bioassay samples are not provided, it is impossible to do an accurate dose assessment" (DOE, 1990, pp. 4-198–4-199, PDF pp. 535–536). The RWP program implemented as part of WSRC Manual 5Q1.1 would have enabled the effective execution of the RPRT-0092 completeness survey designed by NIOSH, but such a program did not exist at SRS until after the DuPont era in the early 1990s.

Second, the RPRT-0092 completeness analysis assumes, as a secondary consideration, that job-specific bioassays would be required for permits requiring respiratory protection based on an assumption guided by "today's type of standards" (ABRWH, 2019, p. 20). However, while respiratory protection checkoffs were provided and used on SWPs and job plans, *no* DuPont procedural requirement existed calling for bioassays for permitted work involving respiratory protection. Required job-specific bioassays for permitted jobs calling for respiratory protection were not prescribed in SRS procedures until the early 1990s, after WSRC became the operational contractor.

Third, to establish relevant radionuclide source terms for its permit survey, RPRT-0092 assumes source term characterization based on, in priority order, "work area" identified on the permit, radionuclides identified by DuPont procedures, and facility-based characterizations in Farrell and Findley (1999). However, DuPont era permits did not consistently specify work locations in

SWPs and job plans, and DuPont radionuclide "type and frequency" tables were found to be general and not necessarily updated for changing operations. As previously noted, the WSRC action plan in response to the 1990 Tiger Team noted that SRS was in the process of developing a technical basis document for the internal dosimetry program that would be "consistent with the requirements of the [then newly issued] Order [5480.11] and appropriate guidance" (WSRC, 1990a, PDF p. 432).

The use of Farrell and Findley (1999), as noted previously, back-applies a WSRC comprehensive, waste-stream-based analysis of source terms to DuPont operations in the 1970s and 1980s for which the actual operations at the time, as well as their complexity, would make such an application of questionable accuracy. Those guidelines were developed in response to a 1998 internal WSRC self-assessment of the bioassay control program that was, in turn, in response to DOE-wide enforcement guidelines that reflected concern over noncompliance with DOE regulatory requirements for occupational radiation protection under Title 10 of the Code of Federal Regulations (10 CFR) Part 835 (promulgated in 1995).

Fourth, RPRT-0092 relies on available permit records to provide a means to "randomly select radiological workers from the various areas at the Savannah River Site" (NIOSH, 2018a, p. 1). However, after repeated data capture attempts, the available permits found were for only one facility, 773-A. While WSRC, in response to DOE Tiger Team findings and its own Radiological Improvement Program, upgraded and formalized sitewide SRS radiological records procedures, the lack of adequate sitewide records retention policies contributed to the apparent unavailability of key DuPont era permit records, which makes it difficult to ascribe any sitewide conclusions about job-specific bioassay data completeness.

The implementation of DOE Order 5480.11 in late 1989 required the new SRS operating contractor, Westinghouse, to combine internal and external dose equivalent, and to apply a 100-millirem monitoring threshold. This, combined with Tiger Team corrective actions for RWPs, source characterization, personnel bioassay compliance, and records retention, directly influenced the major radiological control program upgrades undertaken by WSRC in its Radiological Improvement Program. Key components of this improvement program were the development of a WSRC "Internal Dosimetry Technical Basis Manual" (WSRC, 1990b); a standardized RWP program (WSRC, 1990b) with required job-specific bioassays (starting in 1991) that were required upon respirator use (starting in 1992); and WSRC manual 5Q1.1, "Radiation and Contamination Control Procedures" (WSRC, 1992), updated operating requirements, which replaced general DuPont era DPSOL procedures.

While NIOSH apparently agrees with the significance of these programmatic changes, it disputes their implications for being able to conduct the completeness analysis provided in RPRT-0092. SC&A stands by its observation that the root of the shortcomings found for RPRT-0092's analysis of subCTW permit-indicated, job-specific bioassay data completeness is NIOSH's back application of a number of key WSRC program features and assumptions to prior programs of the DuPont era, without any basis in actual historical policy or practice. The shortcomings of this approach are manifest in the actual results achieved and reported for RPRT-0092.

4 SC&A Response: NIOSH Analysis of Pre-1990 Subcontractor Data

4.1 SC&A finding 6

> For the period 1980–1989, only 20 percent of the identified subcontractor-job plan combinations identified by NIOSH as requiring americium sampling had internal monitoring performed within an acceptable timeframe (i.e., within 2 years for chest counting). [SC&A, 2019a, p. 12]

4.1.1 SC&A summary of NIOSH response

SC&A summarizes the NIOSH response as follows:

- Exposure potential to americium that is not comingled with plutonium only occurred in two specific SRS areas:
  - F wing of 773-A
  - Multi-Purpose Processing Facility (MPPF) in F Area
- The majority (~70 percent) of americium urinalysis samples also included a plutonium component.
- Americium urinalysis samples can detect intakes many years from the exposure (NIOSH capped the amount of time at 10 years).
- Regarding chest counting for americium:
  - Only 0.4 percent of the original intake remains after a few months post intake.
  - Only 0.04 percent of the original intake remains after 2 years post intake.
  - For gaps greater than 2 years, unmonitored dose must be assigned until 1 year before the next sample.
- There are only 15 documented intakes of separated americium at SRS for 1972–1989.
- Eighty-one subCTWs were monitored for americium via urinalysis for 1972–1989 and included routine, special, followup, and termination bioassay.

NIOSH (2020c, p. 16) states the following summary response to finding 6:

> NIOSH has shown that subCTWs had limited exposure to americium contamination and, when they were contaminated, Health Physics provided follow-up monitoring. A majority of americium incidents and intakes, including those involving subCTWs, occurred in areas where Am-241 was present in a mixture with plutonium radionuclides. Because workers with known intakes are included in the co-exposure americium models, NIOSH can bound doses for all workers, including subCTWs.

4.1.2 SC&A response

SC&A acknowledges the additional information provided by NIOSH but does not necessarily agree with the overall conclusion. SC&A notes that only job plans associated with F-Wing in

773-A (one of the locations where separated americium was a potential for internal exposure) were analyzed in RPRT-0092 and, therefore, are directly relevant to the evaluation of the job-specific monitoring program for separated americium. However, job plans were only available for analysis during the years 1981–1987. No job plans were identified for analysis associated with the MPPF.

The technical basis document (TBD) for SRS (NIOSH, 2005) indicates that americium may have been also separated in the NSR. The TBD describes the general purpose this facility as follows:

> The NSR facility recovers plutonium from a variety of sources including scrap plutonium from offsite sources and from the F B-Line facility. [NIOSH, 2005, p. 25]

The TBD also describes part of the separations process for the NSR as follows:

> Anion Exchange Purification, which removes impurities such as fluoride, aluminum, **americium**, sulfate, and uranium [NIOSH, 2005, p. 25] [Emphasis added.]

SC&A was unable to find additional information concerning the NSR. One possibility is that it is simply a different name for the MPPF. However, the purpose of the MPPF is described as purification of transuranic material (including americium), while the purpose of the NSR is to recycle plutonium. Further clarification from NIOSH would be helpful to determine whether the NSR constitutes an additional location of exposure potential to separated americium.

The NIOSH (2020a) response notes that only 15 intakes of separated americium are documented. However, SC&A believes the key question is whether adequate evidence has been established that the job-specific monitoring program was sufficiently comprehensive to detect the potential for intake during nonroutine operations such as maintenance activities involving subCTWs.

SC&A does not believe that the NIOSH response directly refutes any part of finding 6. Therefore, SC&A maintains the finding that only 20 percent of the subCTWs on job plans identified by NIOSH as having the potential for internal exposure to separated americium were directly monitored. SC&A would further reiterate that this analysis is based on only one of the two (or potentially three) areas where separated americium was handled, and that the analysis was restricted to the years 1981–1987.

4.2 SC&A finding 7

> The total “effectively monitored” population for americium (those monitored directly or have a coworker on the same job plan with a urinalysis result) during the 1980–1989 period is approximately 33 percent. If a urinalysis sample taken during 1991 as a result of an incident in a different SRS location (and is not currently used in the SRS coworker model) is removed, the effective monitored population drops to 26.5 percent. [SC&A, 2019a, p. 12]

4.2.1 SC&A summary of NIOSH response

SC&A summarizes the NIOSH response as follows:

- NIOSH does not agree with SC&A's assessment of the "effectively-monitored" population and calculates the effectively monitored population as follows:
    - Twenty percent were directly monitored.
    - Thirty-six percent were on the same job plan as a directly monitored worker.
    - The effectively monitored population is therefore 20% + 36% = 56%
- SubCTWs were monitored for incidents of americium and alpha contamination.
- Only 3 of 44 subCTWs who received americium monitoring had potential for internal exposure.
- Incident-based and other special internal monitoring is included in co-exposure modeling.
- Bioassay result from a single worker in 1991 can be used.

4.2.2 SC&A response

SC&A fundamentally disagrees with NIOSH's assessment of the effectively monitored population. SC&A states the following in section 5 of its review of RPRT-0092:

> RPRT-0092 introduced the concept of "effective monitoring," which it defined as the total number of workers who were either monitored directly or who were working side by side with a worker who was monitored directly. However, SC&A believes that an unmonitored worker can only be considered "effectively monitored" if they worked side by side with a worker whose internal monitoring result *would hypothetically be included in the development of the SRS coworker model in OTIB-0081*. [SC&A, 2019a, pp. 41-42]

Therefore, only urinalysis results should be included in establishing co-exposure matches for calculating the effectively monitored population because only urinalysis results are utilized in the co-exposure model. In vivo monitoring results should not be included in establishing co-exposure matches because they are not utilized in the co-exposure model. However, in vivo monitoring occurring within an acceptable timeframe is appropriately considered in establishing the directly monitored portion of the effectively monitored population (as calculated by SC&A as 33 percent in finding 7).

SC&A acknowledges that some subCTWs were monitored for incidents involving americium or other alpha contamination; however, the completeness of such monitoring is not as clear. In its response, NIOSH noted:

> Of the 44 subCTWs sampled during the 1980s, there are three subCTWs with potential americium exposures, with one of them confirmed to have received follow-up bioassays. [NIOSH, 2020a, p. 17]

It is unclear to SC&A how the potential for internal americium exposure was determined for these workers. However, SC&A would note that 1 of 3 received followup bioassay (33 percent), which is nearly identical to SC&A's calculation of the effectively monitored population.

SC&A agrees that incident-based bioassay results are included in co-exposure modeling as long as chelation therapy is not utilized. It is not clear to SC&A why this commentary was included in the NIOSH response to finding 7, which only reported on the percentage of effectively monitored workers based on the job plan study in RPRT-0092.

Regarding the 11 co-exposure matches to a single worker's bioassay in 1991, SC&A included these comments in its review of RPRT-0092 for two primary reasons:

1. The samples were taken in M-Area, not the F-Wing of A Area (nor MPPF) where separated americium was handled. Therefore, they do not necessarily represent a job-specific americium monitoring for potential exposures to separated americium material.

2. Bioassay results in 1991 are not currently used in the co-exposure model; therefore, they are not currently used to represent an unmonitored worker. However, NIOSH has indicated the data would be included in future revisions to the SRS co-exposure model and therefore should appropriately be included in the analysis of the effectively monitored worker population analyzed in RPRT-0092.

It should be noted that SC&A *did* include these 11 samples in its analysis described in finding 7 that concluded that 33 percent of the sampled subCTWs were effectively monitored.

4.3 SC&A finding 8

> Many of the workers (around 70–73 percent) who should have been monitored for fission products underwent appropriate internal sampling during the two periods evaluated prior to 1990 (1972–1974 and 1980–1989). However, very few of these monitored workers underwent in vivo counting for fission products. Thus, they are not included in the coworker model developed for SRS and are not considered representative of the unmonitored worker. [SC&A, 2019a, p. 12]

4.3.1 SC&A summary of NIOSH response

SC&A summarizes the NIOSH response a follows:

- There are sufficient data in the co-exposure model to reconstruct doses to the strata including both CTWs and subCTWs:
    - SubCTWs by year included in the co-exposure model for fission products varied from a minimum of zero in 1974 and 1975 to a maximum of 302 in 1990.
    - CTWs by year included in the co-exposure model for fission products varied from a minimum of 37 in 1985 to a maximum of 92 in 1977.
    - The combined strata of subCTWs and CTWs by year included in the co-exposure model varied from a minimum of 54 in the combined period of 1972–1973 to a maximum of 388 in 1990.
- SubCTWs were monitored by special urinalysis up to 1982.
- Approximately 70–73 percent who should have been monitored for fission products underwent appropriate intake monitoring.

- Whole-body counts were considered valid up to 3 years from the date of the job plan.
- SubCTWs are underrepresented in the fission product co-exposure model until 1983; however, prime CTWs performed similar work and are sufficient to bound exposures to subCTWs.
- Analysis of the time-weighted one-person-one-sample co-exposure data, as shown in figure 1 of NIOSH (2020a), indicates no discontinuity from 1972 to 1990.

4.3.2 SC&A response

SC&A and NIOSH appear to largely agree on the percentage of directly monitored workers identified on available job plans. (SC&A reiterates that no analysis of job plans was available for the years 1975–1979.) However, the salient issue is whether the directly monitored workers are representative of the unmonitored workers via inclusion in the co-exposure model. The co-exposure model is based on in vivo monitoring data, not urinalysis data. Similar to the discussion of finding 7 in section 4.2 above concerning the establishment of the effectively monitored population, urinalysis results are not appropriate for use in establishing co-exposure matches for fission products. SC&A found that only approximately 4 percent of the workers identified on available job plans in 1980–1989 were monitored via in vivo methods, and none of the workers were monitored via in vivo in the 1972–1974 period.

In addition, NIOSH indicates that whole-body counts taken 3 years after the job plan were considered valid for this analysis. SC&A only located such a timing requirement in RPRT-0092 for americium. However, SC&A notes that the original sampling plan indicated the following:

> A CTW being monitored means the worker was bioassayed per the RWP requirement. For a pulled CTW, the ORAU team would use available bioassay data included in NOCTS **to determine if worker was bioassayed within one year from date of RWP sign-in, either by urinalysis or *in vivo* analysis for all radionuclides listed on the RWP other than tritium (H3)**. [NIOSH, 2018a, p. 2] [Emphasis added.]

Furthermore, NIOSH procedures in ORAUT-OTIB-0060, revision 02, "Internal Dose Reconstruction" (NIOSH, 2018b), dictate the following concerning establishment of unmonitored periods:

> A long-lived, long-retained nuclide (e.g., plutonium and uranium) can be retained for decades with continuous excretion of small amounts. One result after many years of employment can contain activity from all previous intakes and provide information for determining an intake amount for all previous years and, in such a situation, a lack of bioassay samples for several years would not be considered unmonitored because an upper bound can be placed on the intake. This is not true for nuclides that are eliminated relatively rapidly from the body (e.g., ^{137}Cs and ^{3}H). . . .
>
> - Long-lived, long-retained nuclides include all absorption types of plutonium, uranium, and americium, unless the only monitoring method is chest counting.

> Types F and M are not retained for significant periods in the lungs and the rules for short-retained radionuclides must be followed.
>
> For short-lived or short-retained radionuclides (including ^{137}Cs, ^{106}Ru, ^{144}Ce, and ^{90}Sr) during potential exposure periods:
>
> - Missed dose is calculated in the intervals where there are bioassay results; other periods are considered to be unmonitored. **Gaps of greater than 2 years between results are considered to be unmonitored.** [NIOSH 2018b, pp. 24–25] [Emphasis added.]

Therefore, SC&A maintains that the effectively monitored populations are approximately 70 percent and 74 percent for the periods 1972–1974 and 1980–1989, respectively.

4.4 SC&A finding 9

> SC&A does not find that the data collected as part of the RPRT-0092 review support the premise that subcontractors on job plans that should have required internal monitoring for americium were either directly monitored (around 20 percent) or, alternately, appropriately represented in the derived coworker models for SRS (around 13 percent). [SC&A, 2019a, pp. 12–13]

4.4.1 SC&A summary of NIOSH response

The NIOSH response to this finding is mainly derived from its response to finding 7 as described above. The following bullets summarize the NIOSH response:

- NIOSH further reiterates that most americium exposure involved mixtures of plutonium and americium.
- RPRT-0092 found that 80 percent of the subCTWs identified were sampled for plutonium during the same period.
- In attachment B, NIOSH (2020a) provides examples of 14 contamination incidents that were associated with some of the identified americium urinalysis results for subCTWs.
- The effectively monitored population should be 56 percent (rather than the 33 percent calculated by SC&A).

4.4.2 SC&A response

SC&A acknowledges that the majority of exposures to americium would include a plutonium component. NIOSH has not proposed using plutonium monitoring as a method for reconstructing doses to americium. However, any such method (for example applying a ratio to plutonium intakes) would not be applicable to workers handling separated americium.

SC&A further acknowledges the incident examples provided in attachment B and discusses the specifics of each incident in table 1 below. As discussed in section 3.4 (finding 4), special monitoring associated with incidents should not be conflated with completeness issues associated with the job-specific monitoring program. Nonetheless, SC&A notes that none of the incident examples were prior to 1980, and only one incident example occurred in an area with the

potential to have separated americium (reference entry B-10). As stated in its discussion of finding 7 (section 4.2 above), SC&A maintains that the effectively monitored population is approximately 33 percent for the only period with job plans to evaluate the job-specific monitoring program (1981–1987). SC&A maintains its position that it does not believe the effectively monitored population, as evaluated in NIOSH (2019a) and SC&A (2019a), supports the premise that workers who should have been monitored by job-specific bioassay were monitored sufficiently, or alternately, adequately represented in the derived co-exposure model utilized to assign unmonitored exposures. However, SC&A notes that any such judgments as to the completeness of the job-specific monitoring program are policy decisions that are strictly under the purview of the SRS work group and full Advisory Board.

Table 1. Summary of the date and location of 11 incident examples presented in attachment B of NIOSH (2020a)

SRDB ref. ID (NIOSH 2020a figure)	Date of incident	Location of incident	SC&A notes and comments
45096 PDF pp. 290–294 (B-1)	2/11/1980	773-A, Laboratory B-147	Noted as a potential plutonium assimilation. Worker was designated as a "Construction Division sheet metal [redacted]," though it is not clear to SC&A that this necessarily denotes a subCTW. A formal pre-plan meeting was not held as specified by DPSOP-40. No respiratory protection was required or used, though the incident investigation noted this was contrary to typical Savannah River Laboratory practice. Continuous monitoring was required by the Radiation Control Inspector (RCI), but at some point during the work, the RCI left to perform other required job functions. The constant air monitor in the incident location indicated airborne contamination that was a factor of 6 higher than the radioactivity concentration guide but was not high enough to sound the alarm due to the set points on the monitor. Contamination was noted by the sheet metal [redacted] when the energy employee (EE) noticed dust on their gloves. Incident investigation concluded: "The Construction Division employee received an uptake of [plutonium] as a result of moving and working around the hood in B-147 because the need for adequate respiratory protection was not recognized. A contributing factor to the assimilation was a lack of effective communication between Construction Division, Custodian, and Radiation Control personnel to define adequate work procedures" (SRDB 45096, PDF p. 293). It is unclear what type of bioassay results were performed (Pu, or Pu and Am).
179286 PDF p. 4 (B-2)	May 1983	High Level Caves, Cell #16	The EEs performing the job are described as "construction mill wrights," and it is not clear to SC&A that they were necessarily subCTWs. No identifying information is provided for the EEs involved (name or payroll number). The EEs were wearing full face respirators, but after significant airborne contamination was found, the operation was switched to air-supplied suits and a containment hut. The workers were sent for in vivo and in vitro monitoring, though it is unclear whether this would have occurred based on the job-specific program (i.e., due to the respiratory requirements of the job) or only due to the incident nature of the event.
179288 PDF p. 4 (B-3)	11/12/1983	773-A, B-048	The EEs involved in this incident were described as "construction electricians"; however, it is not clear to SC&A that they were subCTWs. No identifying information is provided for the EEs involved (name or payroll number). Although the incident record indicates that all EEs involved received special bioassays, it is not clear what the bioassays were for (Am, Pu, or both).

SRDB ref. ID (NIOSH 2020a figure)	Date of incident	Location of incident	SC&A notes and comments
167194 PDF pp. 234–240 (B-4)	2/27/1985	FB Line, 707-1-F	The EE stated that the contamination incident actually happened the prior day (2/26/1985). It was only the next day when hand and foot monitors detected contamination. The EE submitted two followup urinalysis samples in March 1985; no other urinalysis monitoring was identified for the EE.
167194 PDF pp. 197–221 (B-7)	5/1/1985	FB Line, MLM room #3	Incident report notes that the EE had entered the contaminated area earlier in the day (prior to the discovery that the EE was contaminated) and had not been checked by health physics staff and had only checked their own hands on the “C.R.M.” Contamination was then detected later that afternoon upon exit from the area. The EE submitted urinalysis samples following the incident in May 1985 and also had followup samples submitted in December 1986.
175693 PDF p. 143 (B-9)	10/4/1985	FB Line, CM #2	Incident involved a containment hut that was placed on scaffolding; the EE passed underneath the scaffold and was contaminated. No other information is provided concerning health physics coverage or other engineering controls in place to prevent the incident. The EE had several followup bioassay samples for Am-Pu during the month of October. No other urinalysis samples for Am-Pu were noted for the EE.
179292 PDF p. 5 (B-10)	7/29/1986	773-A, F-Wing, Target Fuel Fabrication Facility	No name is given in the incident description, though it states that a bioassay sample is “being analyzed” to ascertain that no assimilation occurred. There’s no way to ascertain if it actually happened or what the results of the sample were.
179293 PDF p. 5; 52022 pp. 36–37 (B-11)	9/11/1986	773-A, C-005	NIOSH (2020a) notes that urinalyses for Pu-239 and Am-241 were negative for the workers involved in this incident. However, SC&A can find no direct connection between the urinalysis results cited and the actual incident described. No names or payroll ID numbers are provided in the incident documentation cited. Special urinalysis was performed for a single EE on the incident date and general location (773); however, the incident description appears to indicate that multiple EEs were involved. Furthermore, the remarks column for the bioassay results for the single EE appears to say “Dumped 11-10-86,” while other results on the same logbook entry indicate “Save” in the remarks column.
179289 PDF p. 4; 165979 PDF pp. 4–10 (B-12)	11/4/1986	773-A, B-005	SC&A only notes that the citation concerning followup bioassay appears to be in error in NIOSH (2020a). The correct reference should be SRDB 52022, PDF pp. 46–47, 52–53, and 70-71, which document Am-Pu bioassay sampling occurring between November 1986 and March 1987. No other Pu-Am bioassay is available for the EE.

SRDB ref. ID (NIOSH 2020a figure)	Date of incident	Location of incident	SC&A notes and comments
175693 PDF p. 68 (B-14)	3/13/1987	FB Line, Mechanical Line Maintenance room #2	The EE received followup urinalysis monitoring in March 1987. No other Am-Pu urinalysis monitoring results were identified for the EE. SC&A also notes that the reference to the followup monitoring should be SRDB 52022, PDF pp. 70–73, rather than SRDB 52022, PDF pp. 96–97.
175693 PDF p. 120 (B-15)	10/21/1987	FB Line, room 410-N	The incident description indicates that the EE was contaminated after entering room 410-N to "look around." The EE received followup urinalysis monitoring in October 1987. No other urinalysis monitoring for Am-Pu was identified for the EE.

4.5 SC&A observation 2

> During the 1972–1974 period, RPRT-0092 only evaluates one job plan/worker combination (Job Plan 46) for potential americium exposure. However, attachment, table D-1 indicates at least one other job plan (Job Plan 47) requiring americium monitoring during this period. Neither of the workers were directly monitored nor had an appropriate coworker monitored for americium. [SC&A, 2019a, p. 13]

4.5.1 SC&A summary of NIOSH response

NIOSH (2019a) should not have indicated that Job Plan 47 was to be assessed for americium monitoring. The job took place in the high-level caves rather than F-Wing, which was the only area under consideration for americium monitoring coverage.

4.5.2 SC&A response

SC&A agrees with NIOSH's explanation and recommends this item be closed by the SRS work group with the acknowledgement that only a single job plan was available for analysis in years 1972–1974 (with no associated internal monitoring) and no job plans were available for analysis in years 1975–1980 and 1988–1989.

4.6 SC&A observation 3

> Only 13 percent of the subcontractor-job plan combinations (17 total) had americium urinalysis performed that could be considered relevant to coworker modeling. Eleven of the 17 urinalysis data points represented a single worker who had a single sample taken in 1991 as a result of an incident that occurred in a different area (M Area) during that year (i.e., representative of a different area and different period). [SC&A, 2019a, p. 13]

4.6.1 SC&A summary of NIOSH response

SC&A summarizes the NIOSH response as follows:

- The original intent of the report was to assess if unmonitored workers worked in the same environments as monitored workers.
- The bioassay sample collected in 1991 both reflects the exposure potential for the individual worker and is representative of the unmonitored workers on the job plan combinations associated with the individual.
- This datum would be incorporated into any future revision of the co-exposure model.

4.6.2 SC&A response

Similar to the discussion about fundamental differences in establishing the effectively monitored population, SC&A believes the original intent of the report was to establish that unmonitored workers on individual job plans are represented by monitored workers on the same job plan. From a dose reconstruction standpoint, the unmonitored worker is only represented if the monitoring records associated with that job plan are utilized in the formulation of the co-exposure model.

SC&A agrees with NIOSH that the bioassay sample collected in 1991 reflects the exposure potential for that individual and can be used in that EE's dose reconstruction. The subject of the 1991 urinalysis sample representing 11 of 17 co-exposure matches for americium is discussed in section 4.2 concerning finding 7. At the time of SC&A's review, data beyond 1988 were not used in developing co-exposure intake estimates for americium. This was the impetus for SC&A's observation 3, although it should be noted that SC&A *did* include this bioassay result in its evaluation of co-exposure matches, as noted in the finding 7 discussion above.

NIOSH has indicated the bioassay sample would be included in any revisions of the co-exposure model; therefore, SC&A believes that those unmonitored workers with co-exposure matches to the 1991 bioassay result would be effectively represented. With the exception of discussion concerning representation in co-exposure modeling, SC&A recommends this observation be closed by the work group.

5 SC&A Response: NIOSH Analysis of 1990–1998 Job-Specific Bioassay Data

5.1 SC&A finding 10

> Data for 1990 are lacking. Therefore, 1990 should be included with the period of limited data, 1972–1989, and not bundled in with the year 1991. [SC&A, 2019a, p. 13]

5.1.1 SC&A summary of NIOSH response

According to NIOSH (2020a), "NIOSH believes that 88% direct monitoring for subcontractors is not demonstrably incomplete [NIOSH, 2019a, p. 38]. This satisfies criteria set forth in the *Criteria for the Evaluation and Use of Coworker Datasets*, the implementation guide for co-exposure models [NIOSH, 2020b]. NOCTS data indicate that subcontractors were monitored" (NIOSH, 2020a, p. 21). Table 5-2 in ORAUT-RPRT-0094 "presents the results of an evaluation of NOCTS data that indicates that 89% of the subcontractors who are claimants working in 1990 have some form of internal monitoring data (in vitro and/or in vivo) [NIOSH, 2019d, p. 14]. This compares favorably with subcontractors who are claimants working in 1991–1997, 71% to 94% of whom have some form of internal monitoring data" (NIOSH, 2020a, p. 21).

SRS continued monitoring all site workers during the change in prime contractors. SRS started the implementation of RWPs in 1989 in reactor areas, but not sitewide until 1991. Nonetheless, SRS continued to sample subCTWs in 1990.

5.1.2 SC&A response

The 88 percent NIOSH quoted from table 4-5 of RPRT-0092 (NIOSH, 2019a, p. 38) covers the entire period of 1990 through 1998, not just 1990, so it cannot be used to address the lack of data (especially the number of RWPS specifying radionuclides to be monitored) for the one year of 1990.

Because ORAUT-RPRT-0094 (NIOSH, 2019d) was issued in October 2019, just prior to SC&A's November 2019 evaluation (SC&A, 2019a) of RPRT-0092, the bioassay information from NOCTS in ORAUT-RPRT-0094 and the data in table 5-2 of ORAUT-RPRT-0094

(presented as table 6 in NIOSH's (2020a) response) were not included in SC&A's evaluation of RPRT-0092. NIOSH's evaluation of NOCTS data in ORAUT_RPRT-0094 indicates that 89 percent of the subcontractors who are claimants working in 1990 have some form of internal monitoring data, in vitro and/or in vivo (table 5-2, NIOSH, 2019d). Eighty-nine percent of the subcontractors bioassayed in 1990 is similar to the percentage bioassayed during the following period of 1991 through 1998. However, the RPRT-0092 issues concerning the lack of 1990 RWPs (number of RWPs, specification of radionuclides, etc.) still remain because the percentage of workers bioassayed does not address these issues.

If internal monitoring is not a particular issue for 1990 (as NIOSH's response indicates), why doesn't 1990 stand alone as the other years do for the period 1992 –1998? For example, 1990 is included with 1991 (i.e., 1990–1991) in tables 4-1, 4-6, 4-10, 4-13, and 4-16 of RPRT-0092, and table 13 of NIOSH's response (NIOSH, 2020a, p. 36). Bundling 1990 with 1991 indicates a lack of RWP information for 1990 and/or 1991 to stand alone. This indicates similar work plan issues as identified in the previous era.

5.2 SC&A finding 11

> For both the 1972–1989 and the 1990–1998 periods, when considering all radionuclides requiring internal monitoring per work permit, as opposed to "at least one radionuclide" requiring monitoring, the percentage of monitored workers drops significantly (particularly in the earlier periods). Directly monitored workers ranged from 47 percent to 77 percent (in comparison to 76–96 percent in RPRT-0092), and effectively monitored workers ranged from 55 percent to 89 percent (in comparison to 85–99 percent in RPRT-0092). [SC&A, 2019a, p. 13]

5.2.1 SC&A summary of NIOSH response

NIOSH (2020a, p. 23) states:

> The original intent of this work was to determine if subCTWs were monitored working in the same environments as other workers. NIOSH proposed to randomly select radiation work permits to demonstrate this by identifying all subCTWs on an RWP, retrieving all their bioassay results, and matching these required bioassays to bioassays actually performed. **The sampling plan, which was used only for the 1990-1998 data, called for calculating a point estimate and a 95% confidence interval for the percentage of subCTWs that had <u>all</u> required bioassay.** However, in RPRT-0092, a worker was considered monitored if they had at least one bioassay. NIOSH did evaluate percentages of subCTWs monitored for individual radionuclides but did not provide a point estimate for the sum of all bioassays required per the RWP or Job Plans for the subCTWs. NIOSH believes the data given in the report shows that subCTWs were monitored similarly to other workers and that unmonitored subCTWs worked in the same environments as the monitored workers. Summary statistics provided for individual radionuclides support that conclusion.

> NIOSH stands by the results given for effectively monitored workers. Even without consideration of effective monitoring, sufficient numbers of subcontractor trade workers were monitored in the years 1972 through 1998 time frame coupled with internal monitoring data for prime CTWs to develop a co-exposure model for use in reconstructing unmonitored doses. Additional rationale is provided in the NIOSH response to Finding 3. [Emphases added.]

5.2.2 SC&A response

Although an analysis of the percentage of subcontractor workers that had "at least one bioassay" can be performed, it should not be used to indicate that subcontractors, or any workers, were adequately bioassayed as prescribed by an RWP or job plan. A worker could have been on a routine uranium bioassay program but could have been required by a specific RWP or job plan to also have a plutonium bioassay; the uranium bioassay would not count for a plutonium bioassay. Therefore, the data obtained from using analysis based on at least one bioassay being conducted are only a very coarse indication of internal monitoring and should not be used to imply compliance with job plans and RWPs. Results based on at least one bioassay being conducted should be used with caution, and it should be clearly indicated that the results do not necessarily satisfy all the internal monitoring requirements of an RWP or job plan, or adequate internal monitoring. The limitations of using the at least one bioassay concept should be considered when weighing the adequacy of internal monitoring data.

Although there may be sufficient data to develop a co-exposure model using prime CTW and subCTW bioassay data, the original issue to be addressed by RPRT-0092 was to determine if subCTWs were monitored similar to other workers such that the subCTW data were representative of their potential intakes, which is not the same as the amount of data available.

5.3 SC&A observation 4

> SC&A's analysis indicates that identified coworker matches may not be sufficiently representative of the subCTW intakes in all cases unless strict criteria are applied, such as the same craft designation as well as the same date and time of the work performed. [SC&A, 2019a, p. 13]

5.3.1 SC&A Summary of NIOSH response

When NIOSH compared the subCTW plutonium bioassays by craft for 1990–1998, there were no significant differences noted, as indicated in table 4-8 of RPRT-0092 (NIOSH, 2019a).

NIOSH considered the following criteria for matching coworkers:

- an RWP as a small work activity
- an RWP on the same day and time
- similar time periods (i.e., morning or afternoon)
- not the same craft, but the same exposure environment
- exposure environment variation depending on the RWP work

5.3.2 SC&A response

NIOSH responded that when the subCTW plutonium bioassay percentages by craft for 1990–1998 were compared, there were no significant differences noted, as indicated in table 4-8 (NIOSH, 2019a). However, this only indicates that the bioassay frequency among crafts were similar, not necessarily that the exposure potentials were similar.

To check the second and third bullet points (which may indicate similar exposure if craft type is not used as a criteria as NIOSH's recommends) listed in the summary of NIOSH's response above, SC&A reviewed the plutonium bioassay data, with their associated selected coworkers, as presented in table C-3 of RPRT-0092 (NIOSH, 2019a, pp. 98–116). SC&A checked to see if the CTW, which is listed in the last column, signed in on the specific RWP on the same date and worked a similar time period as the unmonitored worker listed in the first column. SC&A found that 25 percent (12 out of 48) of the RWP sign-in dates did not match when the co-exposure method was used. Some were off by a day or up to several weeks; one comparison on page 112 had a difference of 7 months (CTW-411 compared to CTW-460) and were on different RWPs. Additionally, several CTWs listed in the last column were not listed on any of the RWPs to compare the unmonitored worker to (e.g., CTW-181 and CTW-233).

This observation was made to point out the cautions that should be taken into account when considering if subCTW bioassays were sufficiently complete when coworker monitoring information is included in analyzing the fraction of subcontractors monitored.

SC&A finds that this observation has been discussed and the cautionary points brought forth. SC&A recommends closure of this observation.

5.4 SC&A observation 5

> Bioassay data in the 1990s are not entirely free of the earlier data issues. The implementation of methods used to correct for the bioassay deficiencies seen in the 1970s and 1980s did not take place immediately with the change in the contracting company in 1990. [12] It was not a step function that took place in 1990; instead, it took a number of years to identify, address, and effectively implement the changes. For example, there was only one RWP with one subCTW listed for 1990 in RPRT-0092, and specific radionuclides were not required on the RWPs until the mid-1990s. [SC&A, 2019a, p. 13]

5.4.1 SC&A summary of NIOSH response

NIOSH believes that none of these were consequential to operation of the Routine Bioassay Program or to dose reconstruction. NIOSH concurs that it is true that radionuclides were not specified in early RWPs until about 1994. However, NIOSH uses Farrell and Findley (1999) and other information given on the RWP to identify target radionuclides (e.g., task specifications).

NIOSH (2020a, p. 35) states: "The relevant issues and deficiencies that extend into the 1990s that SC&A raises have been previously discussed in detail in this report in the course of

[12] The effective contract change was midnight on March 31, 1989. However, RPRT-0092 separates the operating periods into 1972–1989 and 1990–1989.

responding to the findings and observations." NIOSH further states that, "even though the radionuclide of interest was not documented on the RWP, this did not mean that the subCTW did not have a bioassay taken" (p. 36).

5.4.2 SC&A response

As SC&A pointed out in the response to finding 10, if internal monitoring is not a particular issue for the beginning of the 1990–1998 period, why doesn't 1990 and 1991 stand alone as the other years do for the period 1990–1998? Bundling 1990 with 1991 indicates that there is a lack of information for 1990 and/or 1991 to stand alone.

NIOSH's response to early 1990s internal monitoring issues is that although the radionuclides of interest were not documented on the RWP, this did not mean that the subCTW did not have a bioassay taken. However, as indicated by NIOSH, "the original intent of this work was to determine if subCTWs were monitored while working in the same environments as other workers" (NIOSH, 2020a, p. 23). While the number of bioassays and whole-body counts is an indication of data availability, it is not necessarily an indication that subCTWs were monitored for the correct radionuclides as specified on the RWP while working in the same environment as other workers. This issue was what initiated RPRT-0092's analysis of job plans and RWPs.

Additionally, NIOSH responded that "it is true that radionuclides were not specified in early RWPs until about 1994. However, NIOSH uses Farrell and Findley [1999] and other information given on the RWP to identify target radionuclides (e.g., task specifications)" (NIOSH, 2020a, p. 35). When RWP specifications were incomplete, NIOSH based the assumption for bioassay requirements for the tables in RPRT-0092 on (NIOSH, 2019a, p. 31):

- air monitoring and contamination survey results listed on the RWP
- bioassay requirements for similar RWPs for the same areas and location
- bioassay guidelines and procedures of 1990, 1992, and 1996
- Farrell and Findley (1999)

However this does not provide a direct linkage between bioassays and exposure potential (as would be indicated on a correctly completed RWP) to determine if subCTWs were monitored appropriately; this is especially true in the early 1990s. Farrell and Findley (1999) was intended to provide a scope of the radionuclides used in 1999 and to provide for future changes, not necessarily to be extrapolated into the past. According to the document, its purpose was to correct routine bioassay compliance issues and methodology used to determine facility radiological source terms (indicating these issues previously existed in the 1990s).

The 1997 SRS self-assessment (refer to RPRT-0092, pp. 38 and 39, and figure 4-4) and the DOE 1998 occurrence report illustrates that the implementation of processes that would ensure proper internal monitoring of workers, including subCTWs, per RWP requirements during the period 1990–1998 was not without issues. The report (DOE, 1998b, PDF. pp. 4–5) states:

> The problems concerning the job-specific bioassay program have been determined to be NTS-reportable because these problems are **repetitive**: they

> were **first identified in November 1995**. A concern was provided to WSRC in a DOE-SR Exit Meeting held in December 1995 which stated, "Westinghouse facilities and dosimetry program do not effectively ensure that personnel submit appropriate bioassay samples for evaluation of intakes of radioactive material." WSRC responded with three corrective actions which were to prevent recurrence of the problem. The last action was completed July 31, 1996. These corrective actions included procedure changes to clarify bioassay program requirements, training of RCO first-line supervisors related to their bioassay program responsibilities, and studying the need to revise bioassay program requirements to enhance compliance. [Emphasis added.]

These occurrences indicate that bioassay issues did not end in 1990 and begin again in the late 1990s but were instead present during much of the 1990s.

6 Conclusions

SC&A review of RPRT-0092 focused on two operating eras within the SEC qualification period—Dupont (1972–1989/1990) and WSRC (1991–1998)—as well as the sampling premise and design, sampling execution, and results achieved. SC&A finds its conclusions regarding both the feasibility of RPRT-0092's analysis and the supportability of the results reported to differ primarily, but not exclusively, by these operating periods.

6.1 DuPont era, 1972–1989/1990

For this period, largely encompassing later DuPont-managed operations at SRS, SC&A continues to conclude that NIOSH (1) has been unable to demonstrate the completeness of subCTW job-specific bioassay data and (2) did not accomplish the objectives defined in its sampling plan for the RPRT-0092 analysis.

In its 2019 review of RPRT-0092, SC&A (2019a) established the following for the DuPont era:

1. Lack of actual linkage between job plans and required followup bioassays – No evidence was found of job-specific bioassays being performed in response to SWPs or job plans (this includes the assumption that respiratory protection would necessitate appropriate internal monitoring).

2. Lack of SRS operational representativeness – Only building 773-A job plans and SWPs were found for 1972–1974 and 1980–1989, and none were found for 1975–1979.[13]

3. Lack of procedural requirements or documented practice that required job-specific bioassays based on either SWPs or job plans, or respiratory protection – NIOSH already concluded that DPSOP (or DPSOL) procedures under DuPont were too "general" to be a basis for identifying permit-related, job-specific bioassays.

[13] Specific to separated Am-241, job plans are only available for 1973 (one job plan with no associated internal monitoring) and 1981–1987.

4. The back application of the Farrell and Findley (1999) source characterization criteria to identify relevant radionuclide source terms for DuPont era operations of 1972–1989 is not supported, given the widely varying radioactive materials being handled in earlier years and the lack of a routine, comprehensive characterization process available at that time.

NIOSH's response, that it nonetheless has an "ample number of bioassays" that have dates that can be "associated" with a permit or job plan, and that it can be assumed that bioassays "would have been obtained" based on era-related program procedures, is not relevant to the issue of demonstrating subCTW job-specific bioassay completeness, as the RPRT-0092 evaluation was intended. Without any measure of actual SubCTW and CTW worker bioassay conformance with job plan or SWP bioassay requirements, how does NIOSH speak to data completeness or program implementation? A large or "ample" number of bioassay results, by itself, does not have meaning in this context and would have been available to NIOSH from the start, in any case, without the analysis that RPRT-0092 was originally intended to accomplish. Likewise, how can NIOSH assume that bioassays would have been taken, when an accountable RWP program was not in place before the early 1990s, general DPSOL procedures were interpreted and applied by individual facility managers, and it was found by DOE's Tiger Team in 1990 that SRS management did not hold workers and supervisors accountable for bioassay submission?

SC&A concludes a key source of these issues is NIOSH's unfounded assumption that WSRC radiological control policies, procedures, and practices of the 1990s were in similar use in the 1970s and 1980s, and that permit-indicated, job-specific bioassays can be tied to corresponding job plans, SWPs, and RWPs when, in fact, a radiological permit program requiring job-specific bioassays and sitewide source term characterization was not in place at SRS until the early 1990s. Contributing to the faulty basis for the RPRT-0092 survey is the lack of records, particularly SRS-wide job plans and SWPs, for this time period, compelling NIOSH to limit its review to only one SRS facility, 773-A.

Specific to the results presented in RPRT-0092, SC&A believes that the assessment of job-specific monitoring based on the limited job plans for americium was not successful in establishing that subCTWs were adequately monitored. SC&A's evaluation of the data established that only 20 percent were directly monitored and only 13 percent of unmonitored workers were adequately represented by monitored workers on the same job plan who are included in co-exposure modeling for unmonitored intakes. This results in an effectively monitored population of only 33 percent. These results are further complicated by the fact that only one location (F-Wing of 773-A) was available for analysis of job-specific monitoring of separated americium, with only a single job plan in 1973 (no associated internal monitoring) and the remaining job plans only covering the years 1981–1987. Job plans for other locations of potential exposures to separated americium (i.e., MPPF and possibly NSR) and years under evaluation (part of 1972, 1974–1980, 1988–1990) were not located for evaluation.

6.2 Westinghouse era, 1991–1998

SC&A concludes that subCTW job-specific bioassay completeness can be established, but with some qualifications that remain to be addressed. Most notable is defining when RWPs were sufficiently implemented such that job-specific bioassays can be adequately linked to subCTWs under those permits (e.g., with specific radionuclides and bioassays prescribed, even when

respiratory protection was required) to demonstrate that lapses in subCTW job-specific bioassays in 1996–1997 are not apparent in prior years (1991–1995) and would not preclude co-exposure model inclusion of those data.

Although there were marked improvements in bioassays with the introduction of RWPs in 1991–1992 (refer to figure 4 of SC&A, 2019a), the RWPs did not begin to consistently specify radionuclide bioassay requirements until around 1994–1995 (refer to table 15 of SC&A, 2019a). Filling in the bioassay requirements for early RWPs that were incomplete as was done in RPRT-0092 (p. 31) to derive the percentage of subCTW bioassayed, and effectively bioassayed, requires assumptions about assumed source terms rather than direct linkage between identified radionuclide exposure and required subCTW bioassays. Farrell and Findley (1999) was intended to provide a scope of the radionuclides used in 1999 and to provide a path forward, not necessarily to be extrapolated into the past, as discussed under finding 2. In fact, Farrell and Findley (1999) acknowledge there were earlier bioassay and source term issues that predated their guidance. The ability to ascertain subCTW permit-indicated, job-specific bioassay completeness for the early 1990s in the context of these specific programmatic development issues needs to be confirmed.

Another qualification that needs to be addressed is the “at least one bioassay” concept. Results based on at least one bioassay being conducted should be used with caution, and it should be clearly indicated that the results do not necessarily satisfy all the internal monitoring requirements of an RWP or job plan, or indicate adequate internal monitoring. The limitations of using the “at least one bioassay” concept should be considered when weighing the adequacy of internal monitoring data.

While RPRT-0092 provides relatively higher completeness rates (as compared to the earlier era at SRS) for subCTW job-specific bioassays for the 1991–1998 period, the validity of those rates remains questionable without addressing available evidence of actual bioassays being performed on the basis of individual RWPs and defined source terms. It is clear that the number and use of RWPs grew steadily in the early 1990s under WSRC procedural changes but did not consistently specify key radionuclides until 1994–1995 (SC&A, 2019a, table 15). Given the WSRC program deficiency on this issue in 1996–1997, leading to DOE enforcement action in 1998, it remains critical for NIOSH to demonstrate completeness for these preceding years consistent with the objectives of its RPRT-0092 sampling plan.

6.3 Overall

The evaluation in RPRT-0092 was designed to answer an overarching question posed by the Advisory Board in 2017, given the clear gap in subcontractor RWP-required, job-specific bioassays identified by WSRC for 1997: Did such bioassay data incompleteness at SRS predate the WSRC finding in 1997? The NIOSH sampling approach was directed at answering that question by surveying SWPs, job plans, and RWPs for 1972–1998 to ascertain the rate of subcontractor job-specific bioassay performance consistent with radionuclides identified as having exposure potential. At the same time, NIOSH was to demonstrate routinely monitored workers were doing the same jobs or tasks as those solely on job-specific bioassay. In its most recent response, NIOSH emphasizes the “ample” amount of routine and special bioassay data for subcontractors, particularly those in the NOCTS claimant database, but cannot demonstrate the

data completeness for job-specific bioassays, at least for 1972–1990, that was the fundamental purpose of the RPRT-0092 analysis.

NIOSH's position, contained in its recent review (NIOSH, 2020c) of SC&A's response to ORAUT-RPRT-0091 (SC&A, 2020), that a "small amount of missing routine or job-specific bioassay samples did not invalidate the radiation protection program at SRS and do not automatically invalidate the vast amounts of available monitoring data to generate a coworker model" misses the point of the RPRT-0092 analysis. It remains unknown to what extent past job-specific bioassays are incomplete, but it is known that the gap in 1997 was significant and the weight of evidence provided by SC&A's review invalidates the inclusion of prior-year subCTW data as complete and representative in the SRS co-exposure model.

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