Draft

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

Review of NIOSH's Response to SC&A's Focused Review of ORAUT-RPRT-0092, 1991–2007

Response Paper

Revision 0
Contract No. 75D30119C04183

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December 15, 2023

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1 Introduction

SC&A was tasked by the Advisory Board on Radiation and Worker Health (ABRWH, Board) Savannah River Site (SRS) Work Group on September 21, 2021, to review the National Institute for Occupational Safety and Health's (NIOSH's) Special Exposure Cohort (SEC) Petition SEC-00103 evaluation report (ER) for the period 1991–2007, with a focus on remaining SEC-related issues stemming from ORAUT-RPRT-0092, revision 00 (ORAUT, 2019; "RPRT-0092"). SC&A subsequently issued its "Focused Review of ORAUT-RPRT-0092, Revision 00, and Remaining Petition SEC-00103 Evaluation Report Period: 1991–2007," on April 22, 2022.

The Board recommended, and the Secretary of Health and Human Services (HHS) approved, that an SEC be designated for:

> All construction trade employees of Department of Energy subcontractors [excluding employees of the following prime contractors who worked at the Savannah River Site in Aiken, South Carolina, during the specified time periods: E. I. du Pont de Nemours and Company, October 1, 1972, through March 31, 1989; and Westinghouse Savannah River Company, April 1, 1989 through December 31, 1990], who worked at the Savannah River Site from October 1, 1972 through December 31, 1990, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort. [ABRWH, 2021, p. 1; HHS, 2021, p. 2]

The basis for this recommendation for 1972–1990 acknowledged that subcontractors conducted a broad range of work activities at SRS and may have worked in high-contamination and high-airborne-radioactivity areas and may have been utilized for short-term high-exposure work tasks (ABRWH, 2021, PDF p. 3). It was also found that subcontractors may have been "transient" and "intermittently tasked with nonroutine radiological jobs under work permits, and thus were not likely enrolled in the routine (including termination) bioassay monitoring program" (ABRWH, 2021, PDF p. 3). The Board also found there to be "insufficient information, including a lack of job-specific radio-bioassay monitoring data for subcontractor construction trades workers, and assurance of workplace monitoring and source term data, to enable NIOSH to estimate with sufficient accuracy all potential internal doses" (ABRWH, 2021, PDF p. 2).

The purpose of SC&A's (2022) focused review was to assess these same programmatic and bioassay data adequacy issues for post-1990 operations at SRS, during the balance of years covered by NIOSH's ER (1991–2007) for the SEC-00103 petition, to ascertain whether these inadequacies may have persisted into that later time period and to assess to what extent, and to what point in time, dose reconstruction with sufficient accuracy may have been affected.

NIOSH issued its response paper to SC&A's focused review on November 22, 2022. In that Response Paper, NIOSH addressed SC&A's five conclusions from the focused review (SC&A, 2022):

1. Sampling premise is not sufficiently grounded in historical SRS practices.

2. Results for direct and effective monitoring may be overstated.
3. Generalized matching is not sufficient.
4. RWP-specified, job-specific bioassay data are incomplete.
5. Feasibility of co-exposure model needs to balance RWP implementation with completeness of coworker data.

This SC&A response paper addresses NIOSH's (2022) specific response to each of SC&A's focused review conclusions and provides an overall position on each NIOSH response, as described in section 2.

2 SC&A's Comments on NIOSH's Response

SC&A's focused review (SC&A, 2022) had the following conclusions. Sections 2.1–2.5 address NIOSH's response to each conclusion and SC&A's comments on that response.

2.1 SC&A (2022) conclusion 1: Sampling premise is not sufficiently grounded in historical SRS practices

SC&A concluded that, "measured against the review criteria used by SC&A's review of RPRT-0092, the sampling premise is not sufficiently grounded in actual WSRC policies, procedures, and practices within the time period 1991–1998" (SC&A, 2022, p. 41). In particular, "while RWPs were implemented by procedure in 1992 (and were being rolled out by WSRC before then), along with more specific target radionuclides listed on RWPs, SC&A finds that demonstrable implementation of these requirements was not apparent in the workplace until 1994–1995, as evidenced by figure 1 and table 2" (p. 41).

NIOSH's response notes that SC&A's conclusion is based "on the change in practice from bioassay specified by procedure to bioassay specified by RWP, not an inadequate RWP program" (NIOSH, 2022, p. 5). It further notes that SC&A's figure 1 and table 2 have "unknowable uncertainties, making all conclusions drawn from Figure 1 and Table 2 within the SC&A Focused Review suspect" (p. 5). NIOSH concludes that "it is neither necessary to have RWPs nor to analyze them to justify the feasibility of making a co-exposure model. Co-exposure models can be created without having any RWPs, so the absence of bioassay requirements on some of the RWPs is irrelevant" (p. 5).

The basis for NIOSH's response appears to be two-fold:

1. "There was a proceduralized, pre-specified routine bioassay program in place in the early 1990s, so the fact that those RWPs [SC&A's cited results in figure 1 and table 2] do not specify the required bioassay is irrelevant for developing co-exposure models" (NIOSH, 2022, p. 4).

2. "The summaries in Figure 1 and Table 2 of the SC&A Focused Review are not part of that specific purpose and were not characteristics captured in the March 2018 inventory (year was characterized but bioassay requirements were not), so the uncertainties in those summary statistics are unknowable" (NIOSH, 2022, p. 4).

2.1.1 Reliance on routine bioassay program

The importance of combining and considering both the routine and nonroutine bioassay programs was explicitly addressed as a cautionary note in Westinghouse Savannah River Company's (WSRC's) 5Q1.1-506 manual procedure, which states:

> **Caution:** It is **EXTREMELY IMPORTANT** to note that the effectiveness of the bioassay program in general depends on combining both the routine program and the non-routine, job-specific program. Any time unusual events occur, or jobs are performed that may expose personnel to unusual hazards, a job-specific program should be considered per Section 5.1.2.1. [WSRC 1992, PDF p. 60]

Section 5.1.2.1 of 5Q1.1-506, also provides that "any time jobs are undertaken with the potential for unknown radiological conditions to occur or unusual radionuclides to be present, a non-routine, job-specific bioassay program should be considered" (WSRC, 1992, PDF p. 57).

As noted in SC&A's review of RPRT-0092:

> Without 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, 2019, p. 21]

Regarding reliance on the routine bioassay program, WSRC made it clear that unique job-related radiological sources entailed job-specific bioassay sampling:

> It is very important to realize that being on a routine sampling program does not automatically cover the bioassay sampling requirement specified on the RWP. In fact, section 5.2.4 of 5Q1.1, 504 "Radiological Work Permit" used to require that the radiological control supervisor identify the RWP bioassay requirements so that they were consistent with 5Q1.1, 506 "In Vivo and In Vitro Bioassay Scheduling and Administration." This link was eliminated because routine sampling programs may not be appropriate for work involving non-routine mixes or concentrations of radioactive material. [Findley, 1997, p. 2]

The distinction between routine and nonroutine bioassay sampling is important to the question of bioassay data representativeness, and whether and how SRS routine bioassay data can be substituted for what may be incomplete nonroutine bioassay data related to job-specific bioassay sampling. SC&A believes such substitution to be problematic, with routine bioassay data not necessarily being representative of subcontractor job-specific bioassays. It also shows that WSRC continued to have programmatic shortcomings in how job-specific bioassays were being implemented as late as 1997.

In terms of demonstrating implementation of Radiological Work Permit (RWP)-directed job-specific bioassays, SC&A is simply adopting and referencing NIOSH's own RPRT-0092 analyses for direct and effective matches between RWPs and listed subCTWs or their coworkers,

as noted in conclusion 2. The most recent NIOSH claim that these data and analyses are irrelevant because workers would have submitted job-specific bioassays by procedure, alone, has not been substantiated and is not supported by the historical record. That record shows a lengthy SRS history of worker noncompliance with bioassay submission procedures, culminating in the WSRC self-assessment in 1997 showing a 79 percent shortfall in RWP bioassay submissions.[1]

As noted in SC&A's (2022, p. 20) focused review:

> Despite a Tiger Team finding on non-submission of bioassay samples in 1990, corrective actions to ensure adherence to job-specific bioassay requirements were only taken following a succession of noncompliance findings. These included a 1995 DOE (Savannah River Operations Office) oversight finding, a subsequent 1997 WSRC self-assessment to ascertain whether those workers required to provide job-specific bioassays actually did so, and a 1998 DOE enforcement action and WSRC corrective action program (DOE, 1998; WSRC, [1998b]). As noted by WSRC, while the "expected percent participation implied by 10CFR835 and WSRC 5Q Manual is 100%," it was found that only 21 percent of sitewide workers provided the required job-specific bioassays in the second quarter of 1997 (WSRC, [1998b], p. 2). As indicated by SC&A in its various reviews of the SRS ER, the WSRC survey of job-specific bioassay completeness was limited to 1997, but the independent DOE oversight reviews of 1990 and 1995, coupled with the FEB [Facility Evaluation Board] findings in 1994–1995 (for non-submission of tritium bioassay samples), indicated that the problem persisted throughout the early 1990s under WSRC until 1998 when the bioassay collection and assurance system was overhauled.

NIOSH's claim that any observed changes after 1990 were due to a "change in practice from bioassay specified by procedure to bioassay specified by RWP, not an inadequate RWP program" (NIOSH, 2022, p. 5), does not demonstrate data completeness and, therefore, data representativeness, as sought in RPRT-0092, nor any alternative means to establish such completeness pursuant to DCAS-IG-006, revision 00 (NIOSH, 2020; "IG-006"). It should also be noted that this is not a case of making changes in practice for an inadequate RWP program but rather a substantial exercise over time to define, implement, and hold workers and managers accountable to a new RWP program that emphasized job-specific bioassays and the need to conduct them. While such a requirement for RWPs had been in place, the U.S. Department of Energy (DOE) had found in 1990 that neither DuPont nor WSRC had carried it out (DOE, 1990). While there may have been some lag in reflecting job-specific bioassay requirements and specific radionuclides on RWP forms following procedural upgrades in 1991–1992, the supposition that adequate program implementation nonetheless was ongoing is speculative and inconsistent with the history of this issue at SRS.

[1] This history is outlined in detail in SC&A's 2022 focused review section 3, "Background," and table 1, "Chronology of changes in policies and procedures and RWP bioassay data evaluation."

2.1.2 Irrelevance of RWPs to co-exposure development

NIOSH advances its thesis that RWP implementation, coupled with evidence of job-specific bioassay performance, is not necessary for developing a co-exposure model. However, this position is inconsistent with its RPRT-0092-based assessments since 2017, diverges from the conclusions reached within the SRS Work Group, and does not account for the findings and basis of the existing SEC recommended by the Board and designated by HHS for 1972–1990 for SRS subcontractors, which centers on the lack of established completeness and representativeness of subcontractor job-specific bioassays. These include (ABRWH, 2021, PDF pp. 3–4)):

- Deficiencies in the conduct of permit-driven job-specific monitoring were noted by SRS and the Department of Energy as late as 1997 (e.g., 79% bioassay incompleteness). The lack of procedural assurance for subcontractor participation in bioassay programs, including termination monitoring, as established by SRS, likewise impacts the completeness of subcontractor trades workers monitoring.

- The Board has determined that insufficient information exists to establish the completeness and representation of job-specific bioassays for at least the time period from 1972-1990. The Board recommends a cutoff of the class definition for December 31, 1990, in recognition of the lack of specific internal exposure information concerning the conduct of job-specific monitoring that persisted until at least the end of that year.

- The Board finds that given the nature of radiological work assigned to transient subcontractor construction trades workers, the lack of assurance provided their bioassay monitoring, and identified gaps in the permit-driven job-specific monitoring program, the completeness and representation of subcontractors who were, or should have been, monitored has not been sufficiently established. Therefore, dose reconstruction for unmonitored subcontractor construction trades workers who should have been monitored via the permit-driven job-specific monitoring program are not feasible using the co-exposure models for internal exposures developed by NIOSH.

In the context of the aforementioned incompleteness in job-specific bioassay data and programmatic deficiencies for 1972–1990, the SRS Work Group and SC&A are focused on establishing when these conditions and program circumstances were remedied after 1990 based on information from RPRT-0092 and available WSRC program improvement documentation. A declaration that RWPs and attendant job-specific bioassays are now "irrelevant" because of the availability of "pre-specified routine" bioassay data (NIOSH, 2022, p. 4) to support co-exposure model development resurrects an already repudiated contention that the work group and full Board repeatedly received prior to its action to recommend an SEC class for subcontractors.

The incompleteness of job-specific bioassay data as evidenced by the 1997 WSRC self-assessment survey and the 1998 DOE enforcement action, and evidence that DuPont had not implemented its required RWP program up through 1990, continues to drive the work group's inquiry regarding subcontractor bioassay data completeness. At what point in SRS internal dosimetry program's history was the RWP program defined and implemented adequately such

that required job-specific bioassays were being identified, collected, and recorded reliably so that these data can be considered sufficiently complete, and therefore, representative, to support a co-exposure model for subcontractor workers after 1990? That is the threshold question that needs to be answered to establish a cutoff date for SEC-00103.

2.1.3 "Unknowing uncertainties" in figure 1 and table 2

The available information on job-specific bioassays comes from the surveyed RWPs for 1990–1998, which are the only available records received from SRS that contain that specific information. The statistical uncertainties involved in the use and comparison of such data were recognized at the time, and it was clear that the sampling exercise performed by NIOSH in RPRT-0092 was to provide an indication of data completeness, not a statistically founded analyses as inferred by NIOSH's comments.[2] For example, the full scope of RWPs conducted (numbers, location, dates, workers involved) and corresponding job-specific bioassays is unknown for the early 1990s: The RWPs captured in the initial review and later at the federal repository represent only a partial sampling of facilities, timeframes, and workers based on limited availability of records. SC&A's purpose in performing comparative analyses based on this same sampling of RWPs is to provide an indication of RWP program implementation, not a statistics-based testing of completeness, which was and is not feasible given that the records obtained by NIOSH were intended to be an illustrative sample rather than the entirety of available RWP records.

In this context, it may be relevant to revisit NIOSH's original premise for its RWP sampling, as described in its initial April 13, 2018, "SRS Work Permit Sampling Plan":

> The primary goal of this sampling plan is to randomly select radiological workers from the various areas at the Savannah River Site (SRS), such that an evaluation of monitored and unmonitored workers can be conducted. A concern has been raised by the Advisory Board on Radiation and Worker Health (ABRWH) that a co-worker model, even if the models are stratified by operations workers and construction trades workers, might not be representative for subcontractor CTWs. The ABRWH's Savannah River Site Workgroup's contractor indicated that they would be more comfortable with the co-worker models if it could be demonstrated that monitored subcontractor CTWs and unmonitored subcontractor CTWs worked side by side in the same radiological environment at the same time. The NIOSH/ORAU team determined the best way to demonstrate this monitoring is to randomly pull Special Work Permits (SWPs), Job Plans, and Radiological Work Permits and directly compare the monitoring of subcontractor workers listed as having worked on the individual Work Permit. [NIOSH, 2018, p. 1]

[2] SC&A acknowledges that a Work Permit Sampling Plan was based on a sample size statistical simulation to support the sampling of RWPs with an adequate number of subCTWs (i.e., percentage of subCTWs of interest to within plus/minus 5 percent with 95 percent confidence). However, SC&A's overarching conclusion regarding the overall completeness and representativeness of the RWP job-specific bioassay dataset, and the limitations it imposes for a full statistics-based analysis of subCTW job-specific bioassay data completeness, remains.

The question of representativeness of a co-exposure model for subcontractors was to be based, pursuant to this sampling plan, on a comparison of randomly pulled permits and job plans. The results of that comparison were presented in RPRT-0092 and were found by SC&A to be inconclusive for 1972–1990 given DuPont's reliance on job plans during that time period for which job-specific bioassays were not stipulated. The Board agreed and in its SEC recommendation found "there to be insufficient information, including a lack of job-specific radio-bioassay monitoring data for subcontractor construction trades workers, and assurance of workplace monitoring and source term data" for that time period (ABRWH, 2021, PDF p. 2).

2.1.4 Summary

As SC&A concluded in its 2020 response paper (SC&A, 2020a, p. 44):

> 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, [2019], 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.

In SC&A's view, that demonstration of completeness has yet to be accomplished in NIOSH's response to SC&A's (2022) focused review of ORAUT-RPRT-0092 and remaining Petition SEC-00103 ER period 1991–2007.

2.2 SC&A (2022) conclusion 2: Results for direct and effective monitoring may be overstated

SC&A's (2022) focused review had the following conclusion (pp. 41–42):

> SC&A continues to conclude that, as with the earlier SEC period of 1972–1990, NIOSH did not address all of the radionuclides listed in the RWPs when determining data completeness for job-specific bioassay monitoring, and, therefore, the percentage of matching results for direct and effective monitoring appear to be overstated in the RPRT-0092 summary in section 6.3. This is most relevant for the 1991–1994 period, when (as noted in conclusion 1) many exposure-relevant radionuclides of concern were not yet included in RWPs and inaccurate facility source term assumptions may have been made, as noted by DOE in 1990 (DOE, 1990) and by WSRC in 1999 (WSRC, [1999a]). While RPRT-0092 claims a relatively high percentage of both and direct effective matches between RWPs and listed [subCTWs] or their coworkers for at least one bioassay (averages of 96 and 98 percent, respectively), SC&A's review found these values to be lower (averages of 77 percent directly and 89 percent effectively monitored) when matched against all mandated radionuclides for

> RWPs. These results tend to be dampened in a sitewide comparison, given the much larger numbers of prescheduled bioassays (plutonium, Sr/FPs [strontium/fission products], uranium), but become more apparent at the facility level, as shown in tables 5, 6, and 7. For the period 1991–1994, there are facility-specific instances of significantly lower percentages of directly bioassayed [subCTWs] (e.g., 50 percent for uranium at A-773 and at F-247 in 1991, as shown in table 7). RWPs themselves would not necessarily have included complete in vitro bioassay requirements until March 1999, when WSRC expanded its bioassay specifications to include facility-specific analytic characterization information (WSRC, [1999a]).

According to NIOSH's response (NIOSH, 2022, p. 11), NIOSH did not originally address all of the radionuclides listed (or assumed) on the RWPs when summarizing results in RPRT-0092 but has updated those tallies in their recent response. NIOSH contends that their conclusion has not changed and that a co-exposure model can still be constructed.

NIOSH's (2022) response paper provided some detailed statistical analysis of the RPRT-0092 data in conjunction with SC&A's conclusion 2 (pp. 6–11). This analysis involved the unweighted verses weighted point estimates and confidence intervals of NIOSH's updated tallies. Table 5 of NIOSH's response (NIOSH, 2022, p. 9) summarizes NIOSH's results, reproduced here as table 1.

Table 1. Copy of NIOSH (2022) response paper table 5, "Summary information for conclusion 2"

Monitoring type with definition	Weighted point estimate	95% confidence interval
Direct (at least one required radionuclide)	95.13%	(87.18%, 98.84%)
Direct (all required radionuclides)	75.16%	(68.15%, 81.32%)
Effective (at least one required radionuclide)	97.52%	(87.50%, 99.92%)
Effective (all required radionuclides)	88.13%	(80.14%, 93.74%)

The purpose of RPRT-0092 was to assess the compliance of bioassay monitoring for subCTWs, not to analyze the bioassay data to develop a general population co-exposure model. Therefore, SC&A performed a simple analysis of the percentage of subCTWs monitored by year (SC&A, 2019) as recommended in RPRT-0092, page 11. SC&A analysis was only to indicate areas of compliance, or noncompliance, of subCTW bioassay data to provide markers to aid in an evaluation of the adequacy of the subCTW bioassay data, which is, of course, a subjective decision. SC&A finds that SC&A's original percent of compliance as summarized in tables 9 and 11 of SC&A's (2019) RPRT-0092 review are similar to those in table 5 of NIOSH's (2022) response using their recent detailed statistical analysis and updated tallies (p. 9). Table 2 compares SC&A's values in SC&A's (2019) RPRT-0092 review and NIOSH's (2022) response.

Table 2. Comparison of SC&A's derived percentage monitored (SC&A, 2019) to NIOSH's response paper table 5 (NIOSH, 2022)

Monitoring type with definition	SC&A (2019) tables 9 & 11	RPRT-0092 (2019) table 4-1	NIOSH (2022) weighted point estimate	NIOSH (2022) 95% confidence interval
Direct (at least one required radionuclide)	NA	96%	95.13%	(87.18%, 98.84%)
Direct (all required radionuclides)	77%	NA	75.16%	(68.15%, 81.32%)
Effective (at least one required radionuclide)	NA	98%	97.52%	(87.50%, 99.92%)
Effective (all required radionuclides)	89%	NA	88.13%	(80.14%, 93.74%)

As shown in table 2, SC&A's derived (and those reported in RPRT-0092) percentages of subCTWs monitored are very similar to those presented in table 5 of NIOSH's response, and all percentage values fall within NIOSH's 95 percent confidence interval. Therefore, for the SRS sitewide subCTW average percent directly or effectively monitored (with no further stratification by radionuclide, year, or area) SC&A does not find that there are notable differences in SC&A's 2019 analysis and NIOSH's 2022 analysis of RPRT-0092 subCTW bioassay data. The data in RPRT-0092 were intended to be used as indicators of mandated compliance of subCTW job-specific bioassay data and used as markers to aid in an evaluation of the completeness of the available subCTW bioassay data for use in feasible dose reconstruction. Appendix A of this response paper provides some additional clarification information concerning SC&A conclusion 2.

2.3 SC&A (2022) conclusion 3: Generalized matching is not sufficient

SC&A's (2022) focused review concluded (SC&A, 2022, p. 42):

> Concerning co-exposure model datasets, SC&A found in a focused review of RPRT-0092 plutonium coworker matches during the 1991–1998 WSRC period that, while nearly 96 percent of identified coworker matches involved the same RWP, inclusion of additional criteria (e.g., the same date, time, and craft) decreases this percentage significantly (down to 45 percent) (SC&A, [2019], p. 66). Given the often nonroutine and intermittent nature of [subCTW] jobs under RWPs, sometimes involving unique radiological source terms, SC&A believes such matching needs to be more closely aligned with what is listed on the actual RWP. While the co-exposure implementation guide (NIOSH, [2020]) does not specify an objective measure for data completeness to support the representativeness of a co-exposure model, it does require a determination be made that "there are sufficient measurements to ensure that the data are either bounding or representative of the exposure potential for each job/exposure category at the facility" (NIOSH, 2015, p. 5). SC&A does not consider a generalized match of workers to RWP-specified, job-specific bioassays to satisfy the need to demonstrate that this data set is either bounding or representative of subcontractor exposure potential that should have been monitored by job-specific bioassay.

NIOSH's (2022) response paper to SC&A's focused review states (pp. 12–13):

> Additionally, a laborer could not be used as a coworker for another craft, even if all the other matching criteria were met [ORAUT 2019] [which is RPRT-0092]. There are only two differences between what SC&A is suggesting (same RWP, date, time, and craft) and what was done in ORAUT-RPRT-0092 (same RWP, date, time within 15 minutes, and laborer exception): (1) 15 minutes of time and (2) the exact craft versus the laborer exception. . . .
>
> In summary, coworkers used for effective monitoring matching need only have the same or higher exposure potential than the unmonitored worker. SC&A's criteria of same RWP, same date, same time, and same craft are far too restrictive and do not need to be considered when creating a co-exposure model.

SC&A agrees that the coworker's data from another craft could be used if the coworker had the potential to have the same or higher exposure potential than the unmonitored worker. However, to use a coworker's data from another craft for effective monitoring matching would require that it be apparent that the coworker's craft had the potential to have the same or higher exposure potential than the unmonitored worker. This can create problems with assigning appropriate coworker data 30 years after the RWP was completed, as NIOSH pointed out in RPRT-0092 (ORAUT, 2019, p. 30). SC&A's (2019) review of RPRT-0092 found that the criteria of the same RWP, same date, same time, and suitable coworker were not always met. NIOSH indicated in their 2022 response that a laborer was not used as a coworker in RPRT-0092.

SC&A performed a limited focused review of the RPRT-0092 data to determine how the clarified criteria for coworker matching met the requirements of the same RWP, same date, same time (within 15 minutes), and suitable coworker (which was not to include laborer as indicated in NIOSH's 2022 response). Table 3 summarizes the coworker matches contained in RPRT-0092 and whether they met the appropriate criteria. It should be noted that SC&A evaluated "same time" as within 1 hour rather than the more restrictive 15 minutes. In addition, in instances where SC&A found that the coworker match did not meet the specified criteria, SC&A searched to see if there was an appropriate match. If an appropriate match was found, then these would not contribute to the tallies and percentages in columns 3 and 4, respectively, of table 3.

Table 3. Evaluation of coworker matches in RPRT-0092, appendix C, tables C-3 through C-7

Radionuclide	Number of coworker matches	Number not meeting matching criteria	Percent not meeting matching criteria
Pu	47	11	23.4%
U	18	4	22.2%
Sr	13	2	15.4%
Am	25	5	20.0%
Np	13	6	46.2%

NIOSH's (2022, p. 7) quality assurance review may have corrected these conditions, but those revised data have not been made available to SC&A for review. However, it appears that the

results of NIOSH updating their tally provides for close agreement with SC&A's data analysis as summarized in table 2.

SC&A's concern about the use of coworker data for an unmonitored worker in their review of RPRT-0092 stems from the fact that the purpose of RPRT-0092 was to assess the compliance of bioassay monitoring for subCTWs (SC&A, 2019, 2022). This, by definition, required attention to more details of the data used for unmonitored workers than for a general population co-exposure model. The development of a co-exposure model was not the original purpose of RPRT-0092; therefore, the same criteria may not be applicable to both. For RPRT-0092, SC&A finds that the coworker's data from another craft could be used if the coworker had the potential to have the same or higher exposure potential than the unmonitored worker. However, to use a coworker's data from another craft for effective monitoring would require that it be apparent that the coworker's craft had the potential to have the same or higher exposure potential than the unmonitored worker. This process can sometimes be difficult compared to assigning the same craft for analysis (with the exception of the "laborer" category) in RPRT-0092.

2.4 SC&A (2022) conclusion 4: RWP-specified, job-specific bioassay data are incomplete

SC&A's (2022) focused review concluded (p. 42):

> RWP-required, job-specific bioassay data should be assumed to be substantially incomplete for purposes of demonstrating monitoring data completeness and representativeness for use in a co-exposure model until the end of 1996 (a 100 -percent resampling of all workers on job-specific bioassays was performed for 1997; enhanced accountability and tracking of job-specific bioassays were implemented in 1998). This is based on independent program audits that found that lapses in bioassay submission existed during the 1991–1996 timeframe, spanning from the initial 1990 Tiger Team findings about bioassay program noncompliance to the 1997–1998 WSRC actions in response to DOE field audits, internal FEB findings, and DOE headquarters enforcement action. This is consistent with SC&A's analysis in figures 4 and 5, where SC&A compared the noncompliance fraction (missed bioassay results) of directly bioassayed radionuclides (plutonium, uranium, americium, Sr/FPs neptunium), in terms of being greater or lower for the period 1991–1994, as compared with 1995–1998, respectively. These comparisons are most evocative for uranium and americium, with bioassay noncompliance being significantly higher for the earlier period. The opposite is true for neptunium and Sr/FPs, but by only a small margin over fewer data points. As expected, plutonium is essentially the same for both periods, likely due to its outsized prevalence in SRS operations and by its prescribed, prescheduled monitoring[.]

NIOSH's (2022) response takes issue with data comparisons from RPRT-0092 for which "it was not designed" and for which related "uncertainties" cannot be calculated (NIOSH, 2022, p. 13). These issues are already addressed in sections 2.1 and 2.2 of this paper. The other half of NIOSH's response takes issue with SC&A's citing of contractor self-assessments and DOE regulatory actions regarding site noncompliance with required job-specific bioassay program implementation, with a claim that they are not relevant to co-exposure development.

As stated in past SC&A responses on this subject,[3] such assessments are indeed relevant to data completeness (e.g., for SRS and Los Alamos National Laboratory) if they surface evidence that an operating contractor did not adequately implement its provisions for the RWP job-specific bioassay program such that a large proportion of job-specific bioassays went uncollected. While program noncompliance, by itself, may not be indicative of inadequate bioassay information, evidence that such noncompliance may have led to significant data incompleteness needs to be addressed in the context of co-exposure model development, as provided by IG-006. The Board supported this understanding in its recommendation of an SEC class for subcontractors at SRS for 1972–1990:

> Deficiencies in the conduct of permit-driven job-specific monitoring were noted by SRS and the Department of Energy as late as 1997 (e.g., 79% bioassay incompleteness). The lack of procedural assurance for subcontractor participation in bioassay programs, including termination monitoring, as established by SRS, likewise impacts the completeness of subcontractor trades workers monitoring. [ABRWH, 2021, PDF p. 3]

NIOSH's response also takes issue with and questions how the prescribed provisions of the SRS 5Q1.1-506 manual procedure should be interpreted. For job-specific bioassays, as noted earlier in section 2.1, WSRC explicitly cautioned managers and workers that it was "extremely important" to be aware that the "effectiveness of the bioassay program depends on combining both the routine program and non-routine, job-specific program" (WSRC, 1992, PDF p. 60), and emphasized that "any time jobs are undertaken with the potential for unknown radiological conditions to occur or unusual radionuclides to be present, a non-routine, job-specific bioassay program should be considered" (WSRC, 1992, PDF p. 57).

NIOSH goes on to say that these two provisions from 5Q1.1, quoted in full in section 2.1, "seemingly imply that job-specific samples are non-routine (or special) samples" and that this "implication" contradicts interview comments made by Tom LaBone (NIOSH, 2022, p. 15; ORAUT, 2017, PDF pp. 10–11), an internal dosimetrist at SRS during this time period. He commented that "Job-specific bioassay is a program prescribed in response to a specific event (the job) but is not a special bioassay" (ORAUT, 2017, PDF p. 11). NIOSH (2022) states that, in a 2022 followup interview, "Dr. LaBone acknowledges the confusion that may arise from the 5Q1.1-506 quotes . . . but he maintains that job-specific samples were part of the routine program and were not special samples according to site practices, despite what the procedures say" (NIOSH, 2022, p. 15).

[3] SC&A (2017), pp. 16–21; 2018, pp. 7–9; 2020a, pp. 7–9; 2020b; 2021, p. 7.

SC&A finds that there is no substantiation beyond the interviewee's opinion and recollection[4] that WSRC was implying in these procedural statements that job-specific bioassay samples are "special" samples. The emphatic nature of the cautionary language used and the specific guidance regarding application of job-specific bioassays is clear in its intent.

Special bioassay sampling, a for-cause program, is designed to follow up on field indicators of potential radiological intakes by requiring timely bioassay monitoring for incident-based exposures that may exceed 100 mrem CEDE. What SRS 5Q1.1-506 requires for job-specific bioassay sampling is directed at potential "non-routine" radiological hazards, not already covered by the prescheduled routine program, which were identified or suspected in the workplace prior to the commencement of work and typically prescribed in RWPs.

Job-specific bioassays may have been considered a *categorical* part of the SRS routine internal dosimetry program along with pre-scheduled, baseline, and termination bioassays, but these newly revised 5Q1.1-506 procedures (1) were stressing the critical role that job-specific bioassays played in the effectiveness of SRS bioassay programs and (2) sought to clearly distinguish when nonroutine job-specific bioassays should be considered. Regarding special bioassays, it should be noted that they were addressed in a separate part of 5Q1.1-506.

SC&A finds no contradiction between LaBone's earlier comments and the 5Q1.1-506 procedures. As noted in NIOSH's (2022) response, he acknowledged the distinction between "special" bioassay programs and job-specific bioassays: "Job-specific bioassay is a program prescribed in the response to a specific event (the job) but is not a special bioassay" (ORAUT, 2017, p. 9; quoted in NIOSH, 2022, p. 15). He went on to describe the conditions by which a job-specific bioassay program is prescribed (full interview question and answer provided in appendix B), which is consistent with the premise noted in the SRS 5Q1.1-506 manual and indicated by subsequent WSRC documentation. He described the job-specific bioassay program as enabling individuals to be enrolled "on the spot" for those workers not enrolled in the appropriate prospective routine bioassay program specified on the RWP (ORAUT, 2017, p. 9). This approach is consistent with the a priori identification of jobs with unusual hazards or uncertain radionuclide mixtures for which the routine bioassay program did not already require monitoring and, accordingly, WSRC's procedures would require consideration of job-specific bioassays (WSRC, 1992, PDF p. 60).

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[4] In his 2017 interview, LaBone had emphasized two limitations to his answering questions regarding his experiences at SRS, the second of which raises questions about his interpretation of how field implementation of the job-specific bioassay program was intended in practice (ORAUT, 2017, p. 1):

- I don't have perfect recollection of all the events and their sequence in time. Nevertheless, I have answered everything to the best of my ability and have tried to submit documents supporting my comments when possible.
- I had very specific duties during my time at SRS that seldom lead [sic] to direct involvement in facility radcon issues. Thus, I may not be very helpful in answering detailed questions related to how something was done in the field. The one exception to this was the prescription of special bioassay programs, which starting in the early 1990's was the responsibility of the internal dosimetrists like me.

Regarding the corroboration by Dennis Hadlock (a former SRS health physicist) of LaBone's recollection that at "at some point in 1991, field procedures were changed to require RadCon to call the internal dosimetrist for a suspected intake" (NIOSH, 2022, p. 15), his comments appear to address, again, the special bioassay program (i.e., involving suspected intakes), not the nonroutine job-specific bioassay program (ORAUT, 2022a)

As it stands, the SRS 5Q1.1-506 manual requirement is precise and clear on how the RWP-directed, job-specific program was to be implemented and, in the judgment of SC&A, remains the authoritative record for these WSRC requirements. Furthermore, the specifics of how this program was implemented in practice are corroborated by later WSRC documentation, including Findley (1997) and WSRC (1998a, 1998b, 1998c, 1999b).

On the question of whether, like the Sandia example cited by NIOSH (from a Board discussion; ABRWH, 2022, PDF pp. 67–70), there exists a database that may contain the "most highly exposed workers" that could be compared with the existing NIOSH internal dosimetry database, SC&A noted it had no objections to reviewing any such available database for SRS. NIOSH's response cited a "Track" database containing "special" bioassay samples that may encompass such worker exposures (NIOSH, 2022, p. 16). NIOSH presented this information during the March 2023 SRS Work Group meeting. At the time of that meeting, NIOSH was still in the process of obtaining the actual Track dataset from SRS, which was made available to SC&A in June 2023. Appendix C describes SC&A's review and characterization of the Track database and compares the Track entries with available SRS electronic bioassay data.

From that review, SC&A concludes that while the Track database represents a new dataset of for-cause or incident-based "special" bioassays for SRS in the 1990s, it does not appear to include positive bioassay results collected as part of the routine and nonroutine (i.e., RWP job-specific) bioassay program. This is borne out by the cross-comparison of positive bioassay results with Track database entries in appendix C, table C-7, where SRS workers with positive bioassay results for the sample analyzed were found to be excluded from Track ranging from 75 percent to 86 percent for primary radionuclide except for uranium (U)-235 (one sample, 0 percent), plutonium (Pu)-239 (19 samples, 37 percent) and Pu-238 (129 samples, 57 percent).

In this sense, the Track database differs from the Sandia National Laboratories experience with its WebDose database. While Sandia's WebDose database does not contain every breathing zone sample collected, NIOSH notes that WebDose contains 100 percent of the entries in the available derived air concentration-hour (DAC-hr) tracking logbooks, which represent those breathing zone results that exceeded an established threshold (i.e., 10 percent of a DAC-hr) and were forwarded to the Internal Dosimetry department for tracking. This level of corroboration at Sandia that the highest doses are included in the database does not exist for the Track dataset for SRS based on special bioassay results. On the contrary, as table C-7 illustrates, a large percentage of workers with positive bioassay samples are not included in Track.

SC&A concludes that while the Track dataset can provide relevant information as part of a weight-of-evidence basis for developing a co-exposure model, it does not necessarily capture the most highly exposed workers.

2.5 SC&A (2022) conclusion 5: Feasibility of co-exposure model needs to balance RWP implementation with completeness of coworker data

This SC&A conclusion is an overarching one that emphasizes that any conclusion regarding a co-exposure model being feasible would need to review evidence of RWP program implementation and balance that with available indications of data completeness. These considerations are reflected in SC&A's four preceding conclusions, which address both programmatic adequacy and data completeness. This is highlighted in conclusion 5:

> Given conclusion 4, it is also clear that [subCTWs] who were on RWPs and may not have been monitored likely worked alongside coworkers who were monitored according to the RWP requirements. If RWPs can be considered complete and adequate (because the concerns identified in conclusions 1 and 2 have been addressed) and implemented in an accountable manner with the requisite bioassays substantially performed (per conclusion 4), SC&A would consider NIOSH's conclusion valid that the RPRT-0092 sampling review demonstrates sufficient matches (direct and effective) in the 1991–1998 period to support development of a co-exposure model for [subCTWs] on job-specific bioassays who lacked internal monitoring data. While job-specific bioassays and source terms may be incomplete, given the programmatic shortfalls, this is mitigated by two considerations: (1) job-specific bioassays made up only 5 percent of total bioassays by 1997 . . . and (2) a full resampling of job-specific bioassay results for the second quarter of 1997 found no evidence of intakes. Accordingly, a conclusion about the feasibility of a co-exposure model for workers lacking bioassay results for nonroutine work may be reached by balancing the programmatic limitations of the RWPs and job-specific bioassays with the availability of suitable coworker bioassay data (as given in RPRT-0092). [SC&A, 2022, pp. 42–43]

SC&A further explained its rationale:

> For observed monitoring results, a sampling of RWPs during this same period indicates that many workers were directly monitored[5] or on the same RWP as an assumed coworker who was monitored, resulting in their being effectively monitored.[6] The majority of these monitoring results are logically a result of enrollment in the pre-scheduled, routine program and thus do not obviate the deficiencies in completeness of the job-specific monitoring program. However, it must be determined if, and when, the observed coverage of the routine monitoring program is sufficient to justify the representativeness of any subsequent co-exposure model as applied to workers who should have been covered by the deficient job-specific program. [SC&A, 2022, p. 43]

[5] Seventy to 95 percent depending on the year, per SC&A's calculation of direct monitoring for all assumed/required radionuclides associated with a given RWP.

[6] Eighty-three to 99 percent depending on the year, per SC&A's calculation of effective monitoring for all assumed/required radionuclides associated with a given RWP.

NIOSH asked for clarification in an email regarding SC&A's conclusion 5: "It appears this conclusion is a general statement that if conclusions 1–4 are addressed, then SC&A 'would consider NIOSH's conclusion valid…to support development of a co-exposure model'" (NIOSH & SC&A, 2022).

In a responding email, SC&A replied:

> Yes, your interpretation is correct. Our point in conclusion 5 is to emphasize that all of the elements in the preceding conclusions (i.e., bioassay data completeness, RWP matching, programmatic implementation) need to be addressed together and weighed, in order to reconcile the issues raised in the Board's previous SEC deliberation. [NIOSH & SC&A, 2022]

Based on this response, NIOSH determined that a detailed response to conclusion 5 was not necessary

3 Overall SC&A Position Regarding NIOSH (2022) Response Paper

As noted in section 1, SC&A was tasked by the Board's SRS Work Group on September 21, 2021, to review NIOSH's SEC-00103 ER for the period 1991–2007, with a focus on remaining SEC-related issues stemming from RPRT-0092 (ORAUT, 2019). That review was performed in the context of the Board's recommendation and subsequent HHS designation of a SEC class for SRS subcontractors for 1972–1990. That SEC action found there to be "insufficient information, including a lack of job-specific radio-bioassay monitoring data for subcontractor construction trade workers, and assurance of workplace monitoring and source term data, to enable NIOSH to estimate with sufficient accuracy all potential internal doses" (ABRWH, 2021, PDF p. 2). SC&A concludes that NIOSH's overall response in its November 2022 report does not acknowledge the basis for the SEC class so designated and is, therefore, not responsive to the stated purpose of the review:

> The purpose of this review is to assess these same programmatic and bioassay data adequacy issues for post-1990 operations at SRS, during the balance of years covered by NIOSH's ER (1991–2007) for the SEC-00103 petition, to ascertain whether these inadequacies may have persisted into that later time period and to assess to what extent, and to what point in time, dose reconstruction with sufficient accuracy may have been affected. [SC&A, 2022, p. 10]

Instead, NIOSH advances a series of new or previously unaccepted positions (by the Board and its SRS Work Group) regarding how RPRT-0092 should be interpreted and applied, how co-exposure models for SRS should be developed, and how relevant job-specific bioassay completeness should be considered. These positions, as provided in NIOSH's responses, are found by SC&A to be unresponsive to the stated purpose of the SC&A review and not adequately justified. These are summarized as follows:

- NIOSH advances a new thesis, contrary to its own assessments in RPRT-0092 for SRS, that RWPs are "irrelevant" for co-exposure model development (NIOSH, 2022, p. 5), apparently obviating the IG-006 guideline for the need to demonstrate the completeness

and representativeness of job-specific bioassay data that, in this case, would be necessary for demonstrating the adequacy of such models.

- NIOSH also questions the statistical validity of SC&A's application of RPRT-0092 sampling data and comparative analyses for purposes of gaining an indication of bioassay completeness for sampled RWPs in the 1990s. However, NIOSH does not acknowledge that RPRT-0092 performed similar analyses and that it was always understood that the inherent incompleteness of this data made anything beyond an indication of completeness not feasible.

- NIOSH's claim that any observed changes after 1990 were due to a "change in practice from bioassay specified by procedure to bioassay specified by RWP, not an inadequate RWP program" (NIOSH, 2022, p. 5), is not substantiated and does not provide a demonstration of data completeness, and therefore, data representativeness, sought in RPRT-0092, nor any alternative means to establish such completeness per IG-006.

- NIOSH's objection to SC&A's citing of contractor self-assessments and DOE regulatory actions for noncompliance with required job-specific bioassay program implementation, as not being relevant to co-exposure development, misses the obvious implication that any evidence that an operating contractor missed a large proportion of required bioassays may impact the completeness and representativeness of those data for co-exposure model development per IG-006. SC&A's position was accepted by the Board, whose recommendation on this issue was accepted and reflected in the HHS designation of the SEC class for SRS subcontractors 1972–1990.

- Based on one interview and without corroboration, NIOSH's takes issue with and seeks to reinterpret how the prescribed provisions of the SRS 5Q1.1-506 manual procedure were implemented for "non-routine" job-specific bioassays in practice, despite a number of WSRC procedures and policy statements to the contrary.

- NIOSH continues to question how SC&A conducted its matching comparison of bioassay conformance with RWP requirements given its restrictiveness regarding what coworker crafts could be included, but NIOSH does not substantiate whether the unmonitored subCTW would have had equal or less exposure potential than the monitored coworker craft on the RWP.

As noted in SC&A's response to NIOSH regarding conclusion 5:

> Our point in conclusion 5 is to emphasize that all of the elements in the preceding conclusions (i.e., bioassay data completeness, RWP matching, programmatic implementation) need to be addressed together and weighed, in order to reconcile the issues raised in the Board's previous SEC deliberation. [NIOSH & SC&A, 2022]

SC&A concludes that this has not been adequately accomplished to date, as noted in the preceding specific responses to NIOSH's treatment of each of SC&A's conclusions 1–4.

As part of its review of the NIOSH response, SC&A also was tasked during an SRS Work Group meeting to review a "Track" database that NIOSH identified as one that may contain the "most highly exposed workers" that could be compared with the existing SRS internal dosimetry database (NIOSH, 2022, p. 16). From that review, as discussed in appendix C, SC&A concludes that while the Track database represents a new dataset of for-cause or incident-based special bioassays for SRS in the 1990s, it does not appear to include all of the positive bioassay results collected as part of the routine and nonroutine (i.e., RWP job-specific) bioassay program. This is borne out by the cross-comparison of positive bioassay results with Track database entries in table C-7 of attachment C.

SC&A concludes that while the Track dataset can provide relevant information as part of a weight-of-evidence basis for developing a co-exposure model, it does not necessarily capture all of the most highly exposed workers. SC&A did find that in those cases where the Track entries specified a bioassay followup, bioassays were largely performed (95–99 percent) at least within 1 year of the incident. However, it was not apparent to SC&A that these followup bioassays were directly a result of the Track entry (i.e., they could have simply been part of the routine monitoring schedule).

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Appendix A: Clarifications on Conclusion 2

This appendix gives additional clarifications concerning SC&A (2022) conclusion 2.

Figure A-1 and figure A-2 reproduce figures 4 and 5 of SC&A's focused review (SC&A, 2022) of ORAUT-RPRT-0092 (ORAUT, 2019). During the March 22, 2023, SRS Work Group conference call, a member requested clarification of the data in figures 4 and 5. The following modification provides additional information concerning the number of noncompliance versus required bioassays for the RWPs during a time period. The fractions associated with each bar on the graph show first the number of noncompliance subCTW bioassays; the second number is the number of required bioassays for the RWP. For example, there were nine subCTWs that did not submit plutonium bioassays out of 25 required plutonium bioassays for RWPs during the period 1991–1994.

Figure A-1. Directly bioassayed radionuclides with 1991–1994 noncompliance fraction greater than 1995–1998 noncompliance fraction

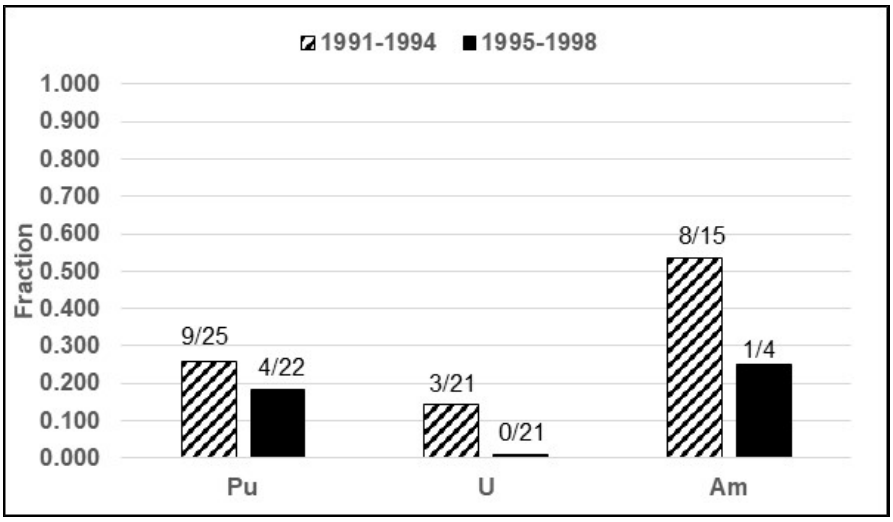
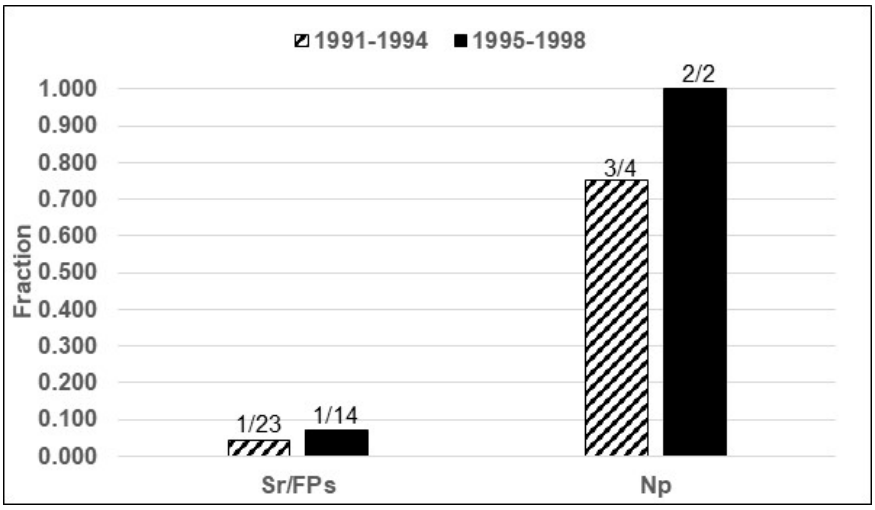


Figure A-2. Directly bioassayed radionuclides with 1991–1994 noncompliance fraction less than 1995–1998 noncompliance fraction



Appendix B: LaBone Interview Response

This appendix reproduces Tom LaBone's October 6, 2017, response to NIOSH question 3 (ORAUT, 2017, pp. 8–9).

Question 3
On July 28, 1998 during the Enforcement Conference with DOE, the following was noted.

WSRC described the purpose of its bioassay sampling program with particular emphasis on the job-specific sampling portion. WSRC stated it had a formal, no intake policy for radionuclides, other than tritium, and that along with its formalized workplace indicators program, including air sampling and contamination surveys, were the primary means of determining whether a worker required bioassay sampling outside of the routine bioassay program. For these cases, special bioassay sampling was performed. (Enforcement Meeting Summary NTS-SR-WSRC-ESH-1997-0001)

Could you please provide the same description of the bioassay sampling program and give particular emphasis on the job-specific sampling program?

Response 3
The slides used for WSRC presentation at the enforcement meeting were apparently not attached to the minutes of the enforcement meeting that are available in SRDB. I have attached the slides to this document. In addition, I have attached Mitch Findley's 1998 presentation at the U.S. Department of Energy Bioassay/Internal Dosimetry Workshop, which gives a good overview of the programs. I also recommend that you look at the 1998 memo from Michael Matheny to Charles Giuntini[7] [all recommended documentation has been reviewed by SC&A].

In a nutshell:

- Special bioassay programs are prescribed for individuals who are suspected of being exposed to radioactive materials that will deliver more than 100 mrem. Special bioassay is a for-cause program, i.e., it is initiated in response to a specific event. The special bioassay program is required by 10CFR835.

- Routine bioassay programs are used to monitor workers who have reasonable potential for exposure to radioactive materials but whom we are certain did not have an intake that warrants a special bioassay program. Routine bioassay is prescribed at arbitrary times (line one's birthday) and not in response to a specific event. Routine bioassay was not used to detect and access intakes of actinides. Rather, it is the final quality control check that routine control measures and workplace monitoring programs worked. The routine bioassay program is not required under 10CFR835.

Job-specific bioassay is a program prescribed in response to a specific event (the job) but is not a special bioassay. Job-specific bioassay is prescribed for two different reasons:

[7] ESH-HPT-98-0552.

- The worker is not enrolled in the appropriate routine bioassay program specified on the RWP, e.g., he did not have the appropriate actinides specified or was not enrolled on a T30 tritium monitoring program. Rather than have the individual return to the dosimetry group to enroll in the right programs and obtain the appropriate RQB, radcon requested the appropriate samples on the spot. These are samples of convenience.

- The worker finished a job with elevated potential for exposure and bioassay was performed to verify that exposures were within predefined limits. These were samples of concern.

Note that neither type of job-specific bioassay is required by 10CFR835. The second type of job-specific sample was most commonly associated with tritium operations in the reactors, where the inexpensive and quickly analyzed spot urine samples were used in much the same fashion as pencil dosimeters are used to monitor external dose during jobs.

Appendix C: Characterization of Track Database

In October 2022, NIOSH interviewed the former lead SRS Internal Dosimetrist regarding how special bioassay samples were administered during the main period of interest (1991–1997). Specifically, the interviewee stated:

> In 1991 I wrote a computer program called *Track* that was used to track the request of special incident related samples and generate reminders to check on the status of the samples. The data files from that program would contain information on all incidents that required special bioassay from 1991 to whenever the functionality of Track was incorporated into ProRad (circa 2002). [ORAUT, 2022c, p. 1]

NIOSH presented this new information during the March 2023 SRS Work Group meeting. At the time of the meeting, NIOSH was still in the process of obtaining the actual Track dataset from SRS, which was eventually made available in early June 2023. SC&A was tasked with examining the database for relevance to current SEC discussions under consideration by the work group. This appendix describes SC&A's review and characterization of the Track database and compares the Track entries with available electronic bioassay data.[8]

C.1. Overview of Track Database

For the years 1991–1997, the Track database has 1,486 entries (rows) that cover 1,191 individual energy employees (EEs) and contain the following information:

- Assigned reference number ranging from 91002 to 97210, where the first two digits represent the year and the last three digits are the temporal sequence of the entry. Each entry covers a single EE.
- EE identifying information: last name, first and middle initials, and social security number (SSN). This information allowed SC&A to determine the employer for the EE and also differentiate prime contractor workers versus subcontractor workers (refer to table C-1).
- Date of the incident (refer to table C-2)
- Occurrence/incident information, such as the location/area/department (refer to table C-3)
- A brief description of the incident, typically less than a dozen words or numbers (refer to table C-4)
- Bioassay specification (e.g., "shift urine (red label for Pu)" or "24-hr urine and fecal for Pu"). SC&A notes that only 950 of 1,486 (or ~64 percent) specified followup internal monitoring.
- Disposition of the entry, which generally indicated whether there was a documented intake associated with the incident (refer to table C-5)

[8] Electronic bioassay data were obtained from the file: "SRS_INDV_NONTRTIUM_LEGACY."

A breakdown of the employer for each Track entry is shown in Table C-1. Subcontractors made up just over 14 percent of the total entries and over 15 percent of the specific individual workers contained in Track. Bechtel (the prime construction worker contractor) made up approximately 9 percent and 10 percent of the Track entries and specific individual workers, respectively. Not surprisingly, SRS Nuclear Solutions and WSRC (the prime contractors) made up the majority of entries and specific individuals.

Table C-1. Number of Track entries (i.e., workers) by main employer

Employer	Number of worker entries (% of total)	Number of individual workers (% of total)
SRS Nuclear Solutions	479 (32.2%)	363 (30.5%)
Westinghouse	395 (26.6%)	311 (26.1%)
Subcontractor	209 (14.1%)	183 (15.4%)
Bechtel	132 (8.9%)	121 (10.2%)
SRS Mission Completion	97 (6.5%)	74 (6.2%)
SRS Remediation LLC	90 (6.1%)	68 (5.7%)
Battelle SRS Alliance	40 (2.7%)	34 (2.9%)
Mixed Oxide (MOX)	23 (1.5%)	17 (1.4%)
Centerra	8 (0.5%)	8 (0.7%)
Unknown	6 (0.4%)	6 (0.5%)
DOE	5 (0.3%)	4 (0.3%)
Parsons	2 (0.1%)	2 (0.2%)
Total	**1,486**	**1,191**

The number of entries and individual workers by year is shown in table C-2. The highest number of entries occurred 1991–1993, then steadily declined 1994–1996. The number of entries and individual workers roughly doubled between 1996 and 1997, though the reason for this is not currently known. The earliest entry during the period of interest in Track occurred on February 2, 1991, and the last entry is dated December 22, 1997.

Table C-2. Number of Track entries and individual workers by year

Year	Number of entries (% of total)	Number of individuals
1991	247 (16.6%)	235
1992	323 (21.7%)	287
1993	299 (20.1%)	295
1994	196 (13.2%)	181
1995	129 (8.7%)	126
1996	98 (6.6%)	88
1997	194 (13.1%)	185
Total	1,486	1,191

Table C-3 presents the breakdown of Track incident entries by the SRS site area. As expected, over 80 percent of the entries were associated with the F and H areas, with a smaller proportion for A and M areas. The "Other Areas" specified were G, L, S, D, K, E, N, P, B, C, Z, and R.

Table C-3. Track entries by general area

Site Area	Number of entries (% of total)
H Area	646 (43.5%)
F Area	558 (37.6%)
A Area	134 (9.0%)
M Area	47 (3.2%)
Other Areas	92 (6.2%)
Unspecified	9 (0.6%)
Total	1,486

When considering the type of incident or occurrence description, SC&A categorized each entry into four general categories:

1. **Airborne Contamination/Inhalation Hazard:** These entries include notable air sampler results, glovebox breaches, or breaches of the personal protective equipment (e.g., bubble suits, respirators) that may have resulted in an intake event.

2. **Personnel Contamination:** These represent when contamination was discovered physically on the worker, such as contaminated shoes, clothing, hands, or face.

3. **Area Contamination:** These are events involving a survey that discovered notable surface contamination in the workspace, including on tools and other equipment.

4. **Notable Routine Internal Monitoring Results:** These entries reflect when normal routine monitoring turned up positive results that were deemed to require followup.

Table C-4 displays the proportion of each of SC&A's categories in the Track database as well as those that could not be categorized because of lack of information. As seen in the table, the largest group of specific incident entries in Track were related to an airborne contamination alarm or other occurrence where intake was suspected (~23 percent). However, the largest proportion gave no information to indicate why the worker was being tracked (~37 percent). SC&A notes that a small proportion of the entries in Track (~3%) were based solely on a significant bioassay result with no field indicators specified. Section C.2 further discusses positive bioassay results and their inclusion in the Track database.

Table C-4. Overview of incident/occurrence events identified in the Track database

SC&A categorized incident type	Number of entries (% of total)
Unknown or unspecified reason	553 (37.2%)
Airborne Contamination/Inhalation Hazard	344 (23.1%)
Personnel Contamination	291 (19.6%)
Area Contamination	247 (16.6%)
Notable Routine Internal Monitoring Result(s)	51 (3.4%)
Total	1,486

Table C-5 presents the Track disposition of each incident entry for the individual EE. The vast majority of entries indicated that there was no documented intake (83 percent), and only 12 percent indicated an actual internal dose assignment. The "Other" category included situations such as:

- Requested sample was never received (10 entries).
- Internal dosimetrist determined internal sampling was not needed (3 entries).
- EE was terminated before sampling could occur (2 entries).

Table C-5. Track-indicated disposition of incident entries

Disposition of incident entry	Number of entries (% of total)
No documented intake	1,232 (83%)
Documented intake	176 (12%)
Unknown	63 (4%)
Other	15 (1%)
Total	1,486

C.2. Comparison of Track Database to Electronic Bioassay Data

As stated in the previous section, SC&A was able to utilize the SSNs in the Track database and bioassay dataset (filename "SRS_INDV_NONTRTIUM_LEGACY") to compare the incidents documented in Track with available followup bioassay results. SC&A found that only 950 of the 1,486 entries (~64 percent) specified a bioassay requirement.[9] SC&A cross-referenced these 950 entries with the electronic bioassay database to ensure that proper internal monitoring was performed within 1 year of the incident date listed in the Track database; the results are shown in table C-6. Radionuclides of the same element were grouped together for this analysis (e.g., enriched uranium, U-234, U-235, and U-238 were all considered "uranium"). It is apparent from the table that nearly all incidents involving plutonium were followed up with bioassay sampling within 1 year of the incident documented in Track. For strontium (Sr)-90 (fission products), uranium, and trivalent actinides (americium (Am)/curium (Cm)/californium (Cf)), approximately 95 percent of the documented incidents in Track that also specified a bioassay followup were sampled within 1 year.

Table C-6. Evaluation of bioassay followup results for Track incidents (when internal monitoring was specified)

Radionuclide group	Monitored within a year	Not monitored within a year
Plutonium (Pu-238/239)	868 (99.7%)	3 (0.3%)
Strontium (Sr-90)	156 (96.3%)	6 (3.7%)
Uranium (enriched, U-234/235/238)	81 (95.3%)	4 (4.7%)
Trivalents (Am/Cm/Cf)	52 (94.5%)	3 (5.5%)
Neptunium (Np-237)	2 (100.0%)	0 (0.0%)

In addition to analyzing bioassay monitoring in relation to the documented Track incidents, SC&A compared all positive bioassay results for the major radionuclide categories against the Track database to evaluate the extent to which the Track database captured all potential incidents that resulted in a positive internal monitoring result. For this comparison, SC&A compared the "received date" of the positive bioassay result with any corresponding Track database entry. SC&A used professional judgment to determine whether the positive bioassay result was likely a

[9] An additional 66 entries only specified that a FastScan in vivo measurement be taken; therefore, these entries were not included in the analysis presented in this section.

result of a documented incident contained in Track. For example, if the positive bioassay was within a reasonable timeframe of a documented incident (i.e., a few months), then it was categorized as likely reflecting the Track entry. However, if the bioassay sample was drastically different temporally (e.g., 6 months to more than a year), then SC&A categorized them as "not likely" associated with the documented Track incident. SC&A's comparison of positive bioassay results to the Track incident entries is shown in table C-7.

As noted in section C.1, the Track database did reflect a portion of incidents that were identified solely because of a notable internal monitoring result (refer to table C-4). However, as shown in table C-7, the majority of positive bioassay results were either not likely reflected in a Track entry or the identified worker was not included in the Track database entirely.

Table C-7. Cross-comparison of positive bioassay results with Track database entries

Radionuclides	# of positive samples	Worker included in Track and positive sample likely reflects incident	Worker included in Track but positive sample likely DOES NOT reflect incident	Worker not included in Track
Sr-90	294	8 (3%)	34 (12%)	252 (86%)
Pu-238	129	49 (38%)	7 (5%)	73 (57%)
Enriched uranium	108	6 (6%)	12 (11%)	90 (83%)
U-234	27	3 (11%)	2 (7%)	22 (81%)
Pu-239	19	8 (42%)	4 (21%)	7 (37%)
U-238	14	2 (14%)	0 (0%)	12 (86%)
Trivalents	5	0 (0%)	1 (20%)	4 (80%)
Np-237	4	0 (0%)	1 (25%)	3 (75%)
U-235	1	1 (100%)	0 (0%)	**0 (0%)**

C.3. SC&A Summary of Track Database Evaluation

The following bullets summarize SC&A's evaluation of the Track database:

- Actual followup internal monitoring (i.e., bioassay) was only specified in approximately two thirds of the incident entries.
- Subcontractor entries made up approximate 14 percent of the documented incidents in Track.
- A notable downward trend in Track entries is observed for 1994–1996; however, there is a significant spike in entries in 1997.
- SC&A's categorization of incidents found that a larger percentage indicated airborne contamination incidents with the potential for intake (~23 percent). However, the largest percentage had no information to characterize what occurred during the incident entry. (~37 percent).
- Only 12 percent of the entries had a documented internal dose assigned (83 percent indicated "no intake").

- Two of the Track entries indicated the worker had been terminated before properly following up with internal monitoring.
- Comparison of Track entries with electronic bioassay records indicates nearly all plutonium incidents had bioassay within one year (99.7 percent).
- The other major radionuclide categories (i.e., fission products, uranium, and trivalent actinides) had identifiable bioassay approximately 95 percent of the time.
- Cross-comparison between positive bioassay results and documented Track entries showed the majority of positive results could not be linked by SC&A to an actual documented incident.