DRAFT

**REPORT TO THE ADVISORY BOARD
ON RADIATION AND WORKER HEALTH**

National Institute for Occupational Safety and Health

COMPARISON OF SC&A'S BLIND DOSE RECONSTRUCTION TO NIOSH'S DOSE RECONSTRUCTION OF CASE #[REDACT] FROM THE ROCKY FLATS PLANT

**Contract No. 211-2014-58081
SCA-TR-DRC2015-CN[REDACT]**

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ABBREVIATIONS AND ACRONYMS

Advisory Board	Advisory Board on Radiation and Worker Health
AP	Anterior-Posterior
CADW	Chronic Annual Dose Workbook
CATI	Computer-Assisted Telephone Interview
CF	correction factor
D	day
DCF	dose conversion factor
DOE	(U.S.) Department of Energy
DOL	(U.S.) Department of Labor
dpm	disintegrations per minute
DR	dose reconstruction
DU	depleted uranium
EE	Energy Employee
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
GM	geometric mean
GSD	geometric standard deviation
hr	hour
ICD	International Classification of Diseases
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules of Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
ISO	isotropic
keV	kiloelectron volts
LOD	limit of detection
MDA	minimum detectable activity
MeV	million electron volts
mrem	millirem
nCi	nanocuries
NIOSH	National Institute for Occupational Safety and Health
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team

pCi/d	picocuries per day
POC	probability of causation
ppm	parts per million
rem	Roentgen equivalent man
RFP	Rocky Flats Plant
ROT	rotational
SD	standard deviation
SC&A	S. Cohen and Associates (SC&A, Inc.)
TBD	technical basis document
TIB	technical information bulletin
WGP	weapons-grade plutonium

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1.0 RELEVANT BACKGROUND INFORMATION

Under Contract No. 200-2009-28555, SC&A was tasked by the Advisory Board on Radiation and Worker Health (Advisory Board) to perform six blind dose reconstructions (DRs) at the May 21, 2013, meeting of the Dose Reconstruction (DR) Subcommittee. SC&A was provided all of the Department of Energy (DOE) dosimetry records; the Department of Labor (DOL) correspondence, forms, and medical records; and the Computer-Assisted Telephone Interview (CATI) Reports that were made available to NIOSH for constructing doses in behalf of these cases. SC&A used two independent approaches to reconstruct occupational external and internal doses for the cases. Both approaches used the available dosimetry records and current guidance from the National Institute for Occupational Safety and Health (NIOSH). The first approach, which is referred to as DR–Method A, used the spreadsheets and other tools developed by NIOSH to calculate the doses, whereas the second approach, referred to as DR–Method B, manually calculated the doses using a deterministic model that is based on central values and first principles.

One of the six draft blind DR reports, *SC&A's Dose Reconstruction of Case #[Redact] from the Rocky Flats Plant* (SC&A 2014), was submitted to the Advisory Board and NIOSH on January 13, 2014. In this report, SC&A presents a comparison between SC&A's and NIOSH's DR methodologies, doses, and resultant Probability of Causation (POC) values for Case #[Redact]. Table 1-1 summarizes the external and internal occupational doses calculated by SC&A (using two independent methods) and the NIOSH-assigned doses for the lung cancer diagnosed in behalf of Case #[Redact]. A detailed comparison of the three methodologies used to calculate doses in behalf of this case is presented in Section 2. Section 3 of this report provides Summary Conclusions.

It should be noted that an explanation is provided regarding the differences in doses and why they occurred; however, SC&A does not make any value judgments regarding which among them may be the more preferred approach. It is our position that further discussions are best addressed by the DR Subcommittee.

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Table 1-1. Comparison of SC&A's Blind Dose Reconstruction to NIOSH's Dose Reconstruction for Case #[Redact]

	NIOSH Lung Doses (rem)	DR–Method A Lung Doses (rem)	DR–Method B Lung Doses (rem)
External Dose (Occupational):			
▪ **Recorded Dose**			
- Photons <30 keV	0.029	0.019	0.018
- Photons 30–250 keV	1.487	1.440	1.551
- Neutrons <10 keV	0.088	0.101	0.099
- Neutrons 10–100 keV	0.026	0.021	0.021
- Neutrons 0.1–2 MeV	0.771	0.691	0.679
- Neutrons 2–20 MeV	0.340	0.313	0.308
▪ **Missed Dose**			
- Photons <30 keV	–	–	0.000
- Photons 30–250 keV	0.037	0.048	0.038
- Neutrons <10 keV	0.028	0.028	0.030
- Neutrons 10–100 keV	0.009	0.006	0.006
- Neutrons 0.1–2 MeV	0.250	0.191	0.199
- Neutrons 2–20 MeV	0.110	0.087	0.089
▪ **Unmonitored Dose**			
- Photons <30 keV	0.001	Not considered	0.012
- Photons 30–250 keV	0.038	Not considered	0.665
- Neutrons <10 keV	0.002	Not considered	0.045
- Neutrons 10–100 keV	0.001	Not considered	0.010
- Neutrons 0.1–2 MeV	0.016	Not considered	0.318
- Neutrons 2–20 MeV	0.007	Not considered	0.148
▪ **Occupational Medical Dose**			
- Photons 30–250 keV	0.084	0.294	0.294
Internal Dose:			
- Plutonium/Americium (Alpha)	46.033	38.676	57.114
- DU (Alpha)	Not considered	Not considered	10.300
Total	**49.357**	**41.915**	**71.944**
POC	**47.51%**	**56.71%**	**55.75%**

2.0 COMPARISON OF METHODOLOGY/DOSES USED BY SC&A AND NIOSH FOR CASE #[REDACT]

Case #[Redact] represents an energy employee (EE) who worked at the Rocky Flats Plant (RFP) from [redact] through [redact], and [redact], through [redact]. According to the DOE records, the majority of the EE's radiation exposure was received while working as a [redact]/ [redact], primarily in the [redact] buildings [redact], [redact], [redact], [redact], and [redact]. (It should be noted that the EE declined the telephone interview.) The EE was monitored for external photon and neutron radiation exposure and internal radiation exposure by urinalyses and lung counts. On [redact], the EE was diagnosed with **lung cancer (squamous cell)** (ICD-9 Code 162.9). It should also be noted that DOE records indicate the EE was a former [redact].

For calculating radiation doses from employment at RFP, all three DR methods primarily relied on guidance in the six Technical Basis Document (TBD) for the RFP (which was issued as six separate documents numbered ORAUT-TKBS-0011-1 through ORAUT-TKBS-0011-06) and *External Dose Reconstruction Implementation Guideline* (OCAS-IG-001). Using the guidance provided in the relevant documents, along with the employee's dosimetry records, NIOSH and SC&A's 'DR Method B' employed a **best-estimate approach** for calculating annual organ doses, while SC&A's 'Method A' used a **minimizing approach** to calculate the lung dose.

A summary of the documents, assumptions, and dose parameters used by each DR method is provided in Table 2-1:

Table 2-1. Comparison of Data and Assumptions Used by NIOSH and SC&A

Parameters	NIOSH	SC&A's DR–Method A	SC&A's DR–Method B
	Recorded Photon Doses		
Records/Guidance Documents	DOE records, TKBS-0011-6, IG-001, and Rocky Flats Workbook 4.29.	DOE records, TKBS-0011-6, and IG-001.	DOE records, TKBS-0011-6, and IG-001.
Work Locations	[redact] Facility all years of employment.	[redact] Facility all years of employment.	[redact] Facility all years of employment.
Energy Range/ DCF	[redact]–[redact] (Exposure): 100% <30 keV – DCF = 0.030 100% 30–250 keV – DCF = 0.986 [redact]–[redact] (Deep Dose Equiv): 100% <30 keV – DCF = 0.050 100% 30–250 keV – DCF = 0.695	[redact]–[redact] (Exposure): 100% <30 keV – DCF = 0.030 100% 30–250 keV – DCF = 0.986 [redact]–[redact] (Deep Dose Equiv): 100% <30 keV – DCF = 0.050 100% 30–250 keV – DCF = 0.695	[redact]–[redact] (Exposure): 25% <30 keV – DCF = 0.030 75% 30–250 keV – DCF = 1.13 [redact]–[redact] (Deep Dose Equiv): 25% <30 keV – DCF = 0.050 75% 30–250 keV – DCF = 0.800
Dosimeter Uncertainty Factor	Not Applied	Not Applied	[redact]–[redact] (<100 mrem) = 2 [redact]–[redact] (>100 mrem) = 1.26 [redact]–[redact] = 1.23
Dose Distribution	Normal distribution; uncertainty based on Monte Carlo	Constant; no uncertainty	Constant; no uncertainty
	Missed Photon Doses		
Records/Guidance Documents	DOE records, TKBS-0011-6, IG-001, and Rocky Flats Workbook 4.29.	DOE records, TKBS-0011-6, and IG-001.	DOE records, TKBS-0011-6, and IG-001.
No. of zeros	5	5	5
LOD Value	0.020 rem	0.020 rem	0.020 rem

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Table 2-1. Comparison of Data and Assumptions Used by NIOSH and SC&A

Parameters	NIOSH	SC&A's DR–Method A	SC&A's DR–Method B
Energy Range/ DCF	[redact]–[redact] (Exposure): 100% 30–250 keV – DCF = 0.986 [redact]–[redact] (Deep Dose Equiv): 100% 30–250 keV – DCF = 0.695	[redact]–[redact] (Exposure): 100% 30–250 keV – DCF = 0.986 [redact]–[redact] (Deep Dose Equiv): 100% 30–250 keV – DCF = 0.695	[redact]–[redact] (Exposure): 25% <30 keV – DCF = 0.03 75% 30–250 keV – DCF = 1.13 [redact]–[redact] (Deep Dose Equiv): 25% <30 keV - DCF=0.050 75% 30–250 keV – DCF = 0.800
Dose Distribution	Lognormal with GSD = 1.6	Lognormal with GSD = 1.52	Lognormal with GSD = 1.52
		Unmonitored Photon Doses	
Guidance Documents	TKBS-0011-6 plutonium coworker model	Not considered.	TKBS-0011-6 plutonium coworker model
Coworker Percentile	50th percentile	Not considered.	95th percentile
Period of Time Assigned	[redact] – 1.05 months [redact] – 5.46 months	Not considered.	[redact] – 1.1 months [redact] – 2 months [redact] – 4 months [redact] – 2 months [redact] – 6 months
Energy Range/ DCF	[redact] (Exposure): 100% <30 keV – DCF = 0.030 100% 30–250 keV – DCF = 0.986 [redact] (Deep Dose Equiv): 100% <30 keV – DCF = 0.050 100% 30–250 keV – DCF = 0.695	Not considered.	[redact]–[redact] (Exposure): 25% <30 keV – DCF = 0.03 75% 30–250 keV – DCF = 1.13 [redact]–[redact] (Deep Dose Equiv): 25% <30 keV – DCF = 0.050 75% 30–250 keV – DCF = 0.800
Dose Distribution	[redact] – Normal with SD 16% [redact] – <30 keV Normal 30–250 keV Triangular	Not considered.	Normal with SD of 30%
		Recorded Neutron Doses	
Records/Guidance Documents	DOE records, TKBS-0011-6, IG-001, and Rocky Flats Workbook 4.29.	DOE records, TKBS-0011-6, and IG-001.	DOE records, TKBS-0011-6, and IG-001.
Energy Range/ DCF	[redact]–[redact] (Exposure): <10 keV – DCF = 1.523 10–100 keV – DCF = 0.751 0.1–2 MeV – DCF = 0.579 2–20 MeV – DCF = 1.004 [redact]–[redact] (Deep Dose Equiv): <10 keV – DCF = 1.332 10–100 keV – DCF = 0.737 0.1–2 MeV – DCF = 0.557 2–20 MeV – DCF = 0.950	[redact]–[redact] (Exposure): <10 keV – DCF = 1.523 10–100 keV – DCF = 0.751 0.1–2 MeV – DCF = 0.579 2–20 MeV – DCF = 1.004 [redact]–[redact] (Deep Dose Equiv): <10 keV – DCF = 1.332 10–100 keV – DCF = 0.737 0.1–2 MeV – DCF = 0.557 2–20 MeV – DCF = 0.950	[redact]–[redact] (Exposure): <10 keV – DCF = 1.523 10–100 keV – DCF = 0.751 0.1–2 MeV – DCF = 0.579 2–20 MeV – DCF = 1.004 [redact]–[redact] (Deep Dose Equiv): <10 keV – DCF = 1.332 10–100 keV – DCF = 0.737 0.1–2 MeV – DCF = 0.557 2–20 MeV – DCF = 0.950
ICRP 60 CF	<10 keV – CF = 0.0755 10–100 keV – CF = 0.0309 0.1–2 MeV – CF = 1.31 2–20 MeV – CF = 0.345	<10 keV – CF = 0.0755 10–100 keV – CF = 0.0309 0.1–2 MeV – CF = 1.31 2–20 MeV – CF = 0.345	<10 keV – CF = 0.0755 10–100 keV – CF = 0.0309 0.1–2 MeV – CF = 1.31 2–20 MeV – CF = 0.345
Dose Distribution	Normal & lognormal distributions; uncertainty based on Monte Carlo	Constant; no uncertainty	Normal distribution; SD = 30%

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Table 2-1. Comparison of Data and Assumptions Used by NIOSH and SC&A

Parameters	NIOSH	SC&A's DR–Method A	SC&A's DR–Method B
		Missed Neutron Doses	
Data Used	DOE records, TKBS-0011-6, IG-001, and Rocky Flats Workbook 4.29.	DOE records, TKBS-0011-6, and IG-001.	DOE records, TKBS-0011-6, and IG-001.
No. of zeros	27	20	27
LOD Value	0.020 rem	0.020 rem	0.020 rem
Energy Range/ DCF	[redact]–[redact] (Exposure): <10 keV – DCF = 1.523 10–100 keV – DCF = 0.751 0.1–2 MeV – DCF = 0.579 2–20 MeV – DCF = 1.004 [redact]–[redact] (Deep Dose Equiv): <10 keV – DCF = 1.332 10–100 keV – DCF = 0.737 0.1–2 MeV – DCF = 0.557 2–20 MeV – DCF = 0.950	[redact]–[redact] (Exposure): <10 keV – DCF = 1.523 10–100 keV – DCF = 0.751 0.1–2 MeV – DCF = 0.579 2–20 MeV – DCF = 1.004 [redact]–[redact] (Deep Dose Equiv): <10 keV – DCF = 1.332 10–100 keV – DCF = 0.737 0.1–2 MeV – DCF = 0.557 2–20 MeV – DCF = 0.950	[redact]–[redact] (Exposure): <10 keV – DCF = 1.523 10–100 keV – DCF = 0.751 0.1–2 MeV – DCF = 0.579 2–20 MeV – DCF = 1.004 [redact]–[redact] (Deep Dose Equiv): <10 keV – DCF = 1.332 10–100 keV – DCF = 0.737 0.1–2 MeV – DCF = 0.557 2–20 MeV – DCF = 0.950
ICRP 60 CF	<10 keV – CF = 0.0755 10–100 keV – CF = 0.0309 0.1–2 MeV – CF = 1.31 2–20 MeV – CF = 0.345	<10 keV – CF = 0.0755 10–100 keV – CF = 0.0309 0.1–2 MeV – CF = 1.31 2–20 MeV – CF = 0.345	<10 keV – CF = 0.0755 10–100 keV – CF = 0.0309 0.1–2 MeV – CF = 1.31 2–20 MeV – CF = 0.345
Dose Distribution	Lognormal with GSD = 1.6	Lognormal with GSD = 1.52	Lognormal with GSD = 1.52
		Unmonitored Neutron Doses	
Guidance Documents	TKBS-0011-6 plutonium coworker model	Not considered.	TKBS-0011-6 plutonium coworker model
Coworker Percentile	50th percentile	Not considered.	95th percentile
Period of Time Assigned	[redact] – 1.05 months [redact] – 5.46 months	Not considered.	[redact] – 1.1 months [redact] – 2 months [redact] – 4 months [redact] – 2 months [redact] – 6 months
Energy Range/ DCF	[redact] (Exposure): <10 keV – DCF = 1.523 10–100 keV – DCF = 0.751 0.1–2 MeV – DCF = 0.579 2–20 MeV – DCF = 1.004 [redact] (Deep Dose Equiv): <10 keV – DCF = 1.332 10–100 keV – DCF = 0.737 0.1–2 MeV – DCF = 0.557 2–20 MeV – DCF = 0.950	Not considered.	[redact]–[redact] (Exposure): <10 keV – DCF = 1.523 10–100 keV – DCF = 0.751 0.1–2 MeV – DCF = 0.579 2–20 MeV – DCF = 1.004 [redact]–[redact] (Deep Dose Equiv): <10 keV – DCF = 1.332 10–100 keV – DCF = 0.737 0.1–2 MeV – DCF = 0.557 2–20 MeV – DCF = 0.950
ICRP 60 CF	<10 keV – CF = 0.0755 10–100 keV – CF = 0.0309 0.1–2 MeV – CF = 1.31 2–20 MeV – CF = 0.345	Not considered.	<10 keV – CF = 0.0755 10–100 keV – CF = 0.0309 0.1–2 MeV – CF = 1.31 2–20 MeV – CF = 0.345
Dose Distribution	Based on Monte Carlo: <10 keV – Normal 10–100 keV – Lognormal 0.1–2 MeV – Normal 2–20 MeV – Normal	Not considered.	Normal with SD of 30%

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Table 2-1. Comparison of Data and Assumptions Used by NIOSH and SC&A

Parameters	NIOSH	SC&A's DR–Method A	SC&A's DR–Method B
		Occupational Medical Doses	
Guidance Documents	DOE records, TKBS-0011-3, ORAUT-PROC-0061, ORAUT-OTIB-0079	TKBS-0011-3	TKBS-0011-3, ORAUT-PROC-0061
Frequency	2 x-ray exams documented in EE's records	Annually, based on Table 3-1 of TKBS-0011-3	Annually, based on Table 3-1 of TKBS-0011-3
Dose Data	TKBS-0011-3 (Table 3-6)	TKBS-0011-3 (Table 3-6)	TKBS-0011-3 (Table 3-6)
Dose Distribution	Normal; SD = 30%.	Normal; SD = 30%.	Normal; SD = 30%.
		Internal Doses – Plutonium/Americium	
Records/Guidance Documents	DOE records, TKBS-0011-5, ORAUT-OTIB-0049, RFP Pu-Am Intake Calculation Tool, RFP Am Lung MDA Calculation Tool, IMBA	DOE records, TKBS-0011-5, ORAUT-OTIB-0049, RFP Pu-Am Intake Calculation Tool, IMBA, CADW	DOE records, TKBS-0011-5, ORAUT-OTIB-0049, IMBA
Dose Determination Approach	Compared coworker dose to missed dose (<MDA reported values) for two employment periods. Compared intakes based on urinalyses versus chest counts.	Calculated intakes based on missed dose (<MDA reported values). Used IMBA and maximum likelihood fitting method to assess both urinalyses and chest count data.	Calculated intakes based on missed dose (<MDA reported values). Compared urinalyses results to chest count data.
Solubility Type	Compared Types F, M, S, and SS (when applicable)	Compared Types F, M, S, and SS (when applicable)	Compared Types F, M, S, and SS (when applicable)
		Missed Tritium	
Records/Guidance Documents	DOE records, TKBS-0011-5, Tritium from Urine Workbook	DOE records, TKBS-0011-5	DOE records, TKBS-0011-5
Dose Determination Approach	Assessed missed tritium from urinalyses results <MDA. Total dose <0.001 and not entered into IREP.	Assessed missed tritium from urinalyses results <MDA. Total dose <0.001 and not entered into IREP.	Assessed missed tritium from urinalyses results <MDA. Total dose <0.001 and not entered into IREP.
		Depleted Uranium (DU)	
Guidance Documents	Not considered.	Not considered.	TKBS-0011-5, IMBA
Dose Determination Approach	Not considered.	Not considered.	Calculated DU dose based on Am-241 lung count MDA data. Intakes entered into IMBA as chronic throughout entire employment period.

2.1 OCCUPATIONAL EXTERNAL DOSE CALCULATIONS

2.1.1 Recorded Photon Doses

The DOE records show that the EE was monitored on a monthly dosimeter exchange frequency throughout employment, and received positive recorded photon doses or doses greater than the limit of detection (LOD) during each year except for [redact]. All three DR methods assumed the EE worked in the [redact] facility and calculated recorded photon doses using guidance provided in the RFP Occupational External Dose TBD (ORAUT-TKBS-0011-6). Organ dose conversion factors (DCFs) were applied in accordance with *External Dose Reconstruction Implementation Guideline* (OCAS-IG-001), as described below.

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NIOSH and SC&A's 'Method A' assumed 100% 30–250 keV photons for reported deep dose measurements and 100% <30 keV photon energy ranges for reported positive shallow dose measurements (shallow dose minus deep dose). Both methods applied organ DCFs in accordance with OCAS-IG-001, Table 4.1a, *Special Dose Conversion Factors for Plutonium* (page 38) for <30 keV photons and Appendix A of for 30–250 keV organ DCFs. (It should be noted that OCAS-IG-001 contains two tables labeled '4.1a;' one on page 38 and a second on page 39.) In addition, NIOSH and SC&A's 'Method A' followed guidance in ORAUT-TKBS-0011-6, which states, for the period 1951 through 1982, the Exposure (R) to organ DCF should be used and, for the period 1983 through 2005, the Hp(10) organ DCF should be used. The photon dose parameters applied by these two DR methods are listed in Table 2-2.

Table 2-2. Photon Energy Fractions and Organ DCFs Used by NIOSH and SC&A's 'Method A'

	1979–1982		1983–1985	
Energy Range	<30 keV	30–250 kev	<30 keV	30–250 kev
Energy Fraction	100%	100%	100%	100%
Exposure Geometry	AP	AP	AP	AP
Organ DCF	0.030	0.986	0.050	0.695

SC&A's 'Method B' applied a dosimeter uncertainty factor to the measured photons, in accordance with guidance in ORAUT-TKBS-0011-6, Tables 6-14 and 6-15. A dosimeter uncertainty factor of 2 was applied during [redact]–[redact] for readings <100 mrem; for readings >100 mrem during [redact]–[redact], a 1.26 factor was applied; and for 1983–1998, a factor of 1.23 was applied.

SC&A's 'Method B' assumed a photon energy fraction of 25% <30 keV and 75% 30–250 keV, as recommended in ORAUT-TKBS-0011-6, Table 6-10, for plutonium workers. In addition to applying the organ DCF values from OCAS-IG-001, Table 4.1a (page 38) for <30 keV photons, this DR method assumed that the rotational exposure geometry was most appropriate for the EE. Therefore, the rotational correction factors cited in the second table labeled Table 4.1a, *Correction Factors for ROT and ISO DCF Values for Bone (RM and Surf), Esophagus, and Lung* (page 39) was applied, as shown in Table 2-3.

Table 2-3. Photon Energy Fractions and Organ DCFs Used by SC&A's 'Method B'

	1979–1982		1983–1985	
Energy Range	<30 keV	30–250 kev	<30 keV	30–250 kev
Energy Fraction	25%	75%	25%	75%
Exposure Geometry	AP	ROT	AP	ROT
Organ DCF	0.030	0.779	0.050	0.552
ROT Correction Factor	NA	1.45	NA	1.45
Adjusted Lung DCF	0.030	1.13	0.05	0.800

Using the EE's dosimetry records and above-cited parameters, NIOSH, SC&A's 'Method A,' and SC&A's 'Method B' calculated nearly identical photon doses, as shown in Table 2-4.

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Table 2-4. Comparison of Recorded Photon Doses

Recorded Photon Doses	NIOSH (rem)	SC&A's 'Method A' (rem)	SC&A's 'Method B' (rem)
<30 keV	0.029	0.019	0.018
30–250 keV	1.487	1.440	1.551
Total	1.516	1.459	1.569

NIOSH entered annual recorded photon doses into the Interactive RadioEpidemiological Program (IREP) as a mean value (normal distribution) with varying standard deviation (SD) values, based on Monte Carlo methods. Both SC&A's 'Method A' and 'Method B' entered doses into IREP as a constant with no uncertainty.

2.1.2 Missed Photon Doses

Missed dose was assigned by all DR methods for photon doses reported as zero readings or less than one-half the applicable LOD value. All three DR methods also counted 5 missed readings and assumed an LOD value of 0.020 rem based on guidance in ORAUT-TKBS-0011-6. NIOSH and SC&A's 'Method A' assigned the missed doses as 100% 30–250 keV, while SC&A's 'Method B' assumed 25% <30 keV and 75% 30–250 keV, which is constant with the energy fraction used for recorded photons. 'Method B's assessment of <30 keV photons resulted in doses <0.001, and therefore, these doses were not entered into IREP.

A comparison of total missed photon doses calculated by the three DR methods is shown in Table 2-5. Although total missed photon doses are nominal and in close agreement, one would have expected SC&A's 'Method A' and NIOSH's doses to be identical. This was not the case, since NIOSH utilized a Monte Carlo method for deriving dose and uncertainty.

Table 2-5. Comparison of Missed Photon Doses

Missed Photon Doses	NIOSH (rem)	SC&A-Method A (rem)	SC&A-Method B (rem)
Lung	0.037	0.048	0.038

NIOSH's annual doses were entered into IREP as a lognormal distribution with uncertainties varying at about 1.63. Both of SC&A's DR methods entered annual missed photon doses into IREP as a lognormal distribution with an uncertainty of 1.520.

2.1.3 Unmonitored Photon Doses

NIOSH and SC&A's 'Method B' assigned coworker doses to the EE for unmonitored periods of employment. Since SC&A's 'Method A' used a minimizing approach to reconstructing doses, this method did not assign any unmonitored photon dose.

Although both NIOSH and SC&A's 'Method B' used the plutonium coworker model doses cited in Table C-4 of the RFP TBD (ORAUT-TKBS-0011-6), the two DR methods differed in their selection of percentile values and number of unmonitored months. NIOSH assumed that the EE, who worked as a [redact]/ [redact], should be assigned the 50th percentile coworker doses for 1.05 months in [redact] and 5.46 months in [redact]. SC&A's 'Method B' selected the 95th

percentile values, based on the EE's job duties and amount of recorded dose the EE received. 'Method B' also assigned coworker doses for 1.1 months in [redact], 2 months in [redact], 4 months in [redact], 2 months in [redact], and 6 months in [redact].

As with the recorded and missed photon doses, NIOSH assumed the energy range of 100% <30 keV and 100% 30–250 keV for the coworker photon doses. Using Monte Carlo methods, the <30 keV doses were entered into IREP as a normal distribution and the [redact] 30–250 keV photons were entered as a normal distribution, while the [redact] 30–250 keV doses were entered as the mode of a triangular distribution.

SC&A's 'Method B' assumed a photon energy range of 25% <30 keV and 75% 30–250 keV. All values were entered into IREP as the mean of a normal distribution with an SD of 30%.

A comparison of unmonitored photon doses derived by the two DR methods is shown in Table 2-6.

Table 2-6. Comparison of Unmonitored Photon Doses

Unmonitored Photon Doses	NIOSH (rem)	SC&A-Method A (rem)	SC&A-Method B (rem)
<30 keV photons	0.001	Not considered	0.012
30–250 keV photons	0.038	Not considered	0.665
Total	0.039	–	0.677

2.1.4 Recorded Neutron Doses

All three DR methods assigned recorded neutron doses based on positive readings reported in the EE's dosimetry records. Recorded neutron doses were calculated using guidance regarding energy ranges and ICRP 60 correction factors (CFs) provided in the RFP Occupational External Dose TBD (ORAUT-TKBS-0011-6). ORAUT-TKBS-0011-6 also recommends using the OCAS-IG-001 Ambient Dose Equivalent-to-Organ DCF for the period 1951 through 1982 and, for the period 1983 through 2005, the Deep Dose Equivalent-to-organ DCF should be used. The neutron dose parameters applied by all three DR methods are listed in Table 2-7.

Table 2-7. Neutron Energies, ICRP CFs, and Organ DCFs Used by the Three DR Methods

	(Ambient Dose Equivalent) 1979–1982				(Deep Dose Equivalent) 1983–1985			
Energy Range	<10 keV	10–100 keV	0.1–2 MeV	2–20 MeV	<10 keV	10–100 keV	0.1–2 MeV	2–20 MeV
ICRP 60 CF	0.0755	0.0309	1.31	0.345	0.0755	0.0309	1.31	0.345
Organ DCF	1.523	0.751	0.579	1.004	1.332	0.737	0.557	0.950

Using the EE's dosimetry records and above-cited parameters, NIOSH, SC&A's 'Method A,' and SC&A's 'Method B' calculated nearly identical photon doses, as shown in Table 2-8.

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Table 2-8. Comparison of Recorded Neutron Doses

Recorded Neutron Doses	NIOSH (rem)	SC&A's 'Method A' (rem)	SC&A's 'Method B' (rem)
<10 keV	0.088	0.101	0.099
10–100 keV	0.026	0.021	0.021
0.1–2 MeV	0.771	0.691	0.679
2–20 MeV	0.340	0.313	0.308
Total	1.225	1.126	1.107

NIOSH employed Monte Carlo methods for deriving doses and uncertainty. As such, some of the neutron doses best fit a normal distribution and some a lognormal distribution. SC&A's 'Method A' entered doses into IREP as a constant with no uncertainty, and 'Method B' entered doses into IREP as a mean of a normal distribution with a 30% uncertainty.

2.1.5 Missed Neutron Doses

All DR methods assigned missed neutron doses for monitored periods that were reported as zero readings or less than one-half the applicable LOD value. NIOSH and SC&A's 'Method B' counted 27 missed readings, while SC&A's 'Method A' assigned missed neutron dose to 20 monitoring periods. NIOSH assumed an LOD value of 0.020 rem from [redact]–[redact] and 0.032 rem from [redact]–[redact], based on guidance in Table 6-20 of ORAUT-TKBS-0011-6. Both of SC&A's DR methods assumed an LOD value of 0.020 for all years. Resultant doses are shown in Table 2-9.

Table 2-9. Comparison of Missed Neutron Doses

Missed Neutron Doses	NIOSH (rem)	SC&A's 'Method A' (rem)	SC&A's 'Method B' (rem)
<10 keV	0.028	0.028	0.030
10–100 keV	0.009	0.006	0.006
0.1–2 MeV	0.250	0.191	0.199
2–20 MeV	0.110	0.087	0.089
Total	0.397	0.312	0.324

NIOSH's annual neutron doses were entered into IREP as a lognormal distribution with uncertainties varying at about 1.55. Both of SC&A's DR methods entered annual missed photon doses into IREP as a lognormal distribution with an uncertainty of 1.520.

2.1.6 Unmonitored Neutron Doses

SC&A's 'Method A' did not calculate any unmonitored neutron doses, since this method employed a minimizing approach to DR. However, both NIOSH and SC&A's 'Method B' did assign unmonitored neutron dose based on the plutonium coworker model described in ORAUT-TKBS-0011-6. Consistent with methods used for assigning unmonitored photon doses, NIOSH selected the <u>50th percentile</u> values from Table C-4 of ORAUT-TKBS-0011-6, while SC&A's 'Method B' selected the <u>95th percentile</u> values. Additional differences in dose calculations included NIOSH assigning unmonitored dose for 1.05 months in [redact] and 5.46 months in [redact], while 'Method B' assigned doses for [redact] and [redact]–[redact] totaling 15.1 months. Total unmonitored neutron doses calculated by the two DR methods are presented in Table 2-10.

Table 2-10. Comparison of Unmonitored Neutron Doses

Unmonitored Neutron Doses	NIOSH (rem)	SC&A's 'Method A' (rem)	SC&A's 'Method B' (rem)
<10 keV	0.002	Not considered	0.045
10–100 keV	0.001	Not considered	0.010
0.1–2 MeV	0.016	Not considered	0.318
2–20 MeV	0.007	Not considered	0.148
Total	0.026	–	0.521

NIOSH employed Monte Carlo methods for deriving doses and uncertainty. As such, the 10–100 keV neutrons best fit a lognormal distribution and all other neutron energies fit a normal distribution. SC&A's 'Method B' entered doses into IREP as a mean of a normal distribution with a 30% uncertainty.

2.1.7 Occupational Medical Doses

All three DR methods calculated an occupational medical dose from diagnostic x-ray procedures required as a condition of employment. NIOSH indicated that they followed guidance cited in the following three guidance documents in order to calculate their occupational medical doses:

1. ORAUT-TKBS-0011-3, *Technical Basis Document for the Rocky Flats Plant – Occupational Medical Dose*, Rev. 01.
2. ORAUT-PROC-0061, *Occupational Medical X-Ray Dose Reconstruction for DOE Sites*, Rev. 03.
3. ORAUT-OTIB-0079, *Technical Information Bulletin: Guidance on Assigning Occupational X-Ray Dose under EEOICPA for X-Rays Administered Off Site*, Rev. 00.

SC&A's DR 'Method A' strictly used guidance provided in the RFP TBD (ORAUT-TKBS-0011-3). SC&A's 'Method B' consulted ORAUT-TKBS-0011-3, as well as ORAUT-PROC-0061.

NIOSH assigned dose for only the two x-ray exams that were documented in the EE's DOE records. Both of SC&A's DR methods calculated annual doses based on guidance in Table 3-1 of ORAUT-TKBS-0011-3. This resulted in the assignment of identical doses for SC&A's 'Method A' and 'Method B,' with NIOSH's occupational medical dose being 35% lower, as shown in Table 2-11.

Table 2-11. Comparison of Occupational Medical Doses

Cancer	NIOSH (rem)	SC&A's 'Method A' (rem)	SC&A's 'Method B' (rem)
Lung	0.084	0.294	0.294

Each DR method entered the annual doses into IREP as a mean value with an SD of 30%.

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2.2 OCCUPATIONAL INTERNAL DOSES

DOE records show that the EE had in vitro bioassay monitoring for plutonium, americium, and tritium via urinalyses during employment at RFP. The EE was also monitored in vivo for plutonium and americium via chest counts. All bioassay results were below the MDA for the given radionuclides and bioassay method. Therefore, to account for any potential undetected internal doses from exposure to plutonium, americium, and tritium, all three DR methods assigned missed and/or unmonitored doses. In addition, SC&A's 'Method B' assumed the EE may have been exposed to depleted uranium (DU). Details associated with the calculation of internal doses are provided below.

2.2.1 Plutonium/Americium Intakes

<u>NIOSH</u>

NIOSH assessed the internal dose from exposure to plutonium and americium by calculating and comparing internal coworker doses and missed dose. NIOSH describes their assessment process in the DR Report, as cited below:

> *Coworker Dose Assignment*
> *Internal coworker dose was assessed in accordance with the Technical Basis Document for the Rocky Flats Plant – Occupational Internal Dose* [ORAUT-TKBS-0011-5]. *For plutonium, Type Super S was considered to be the most claimant-favorable solubility type. . . .*
>
> *Missed Dose*
>
> *Intakes based on plutonium urine bioassay over-predicted intakes based on* [the EE's] *chest counts; therefore, only the chest count data were considered. The mixture of weapons-grade plutonium was applied to the americium-241 intake, based on chest count data, to determine the plutonium -238, plutonium-239, and plutonium-241 intakes. For plutonium, Type Super S was considered to be the most claimant-favorable solubility type based on chest count data (Types M, S, and Super S were considered).*
>
> [The EE] *was monitored for americium by urine bioassay, only during* [the EE's] *first employment period; those bioassay results were assessed as pure americium (solubility Type M) associated separation activities.*
>
> *The chronic intake rate was determined using half the minimum detection activity (MDA) for that radionuclide and assigned as the mode dose, with the maximum dose being twice the mode dose.*
>
> ***Internal dose based on short intake periods . . . may significantly overestimate the actual internal dose when based on missed dose assumptions****. To assure* ***reasonable potential intakes*** *were applied, . . . the internal dose based on the . . .*

> ***missed dose assumptions, was compared to the dose calculated using coworker data****. Because* ***coworker intakes resulted in a significantly lower dose for*** [the EE's] ***second employment period****, those intakes were applied for that period; missed internal dose was applied during* [the EE's] *first employment period.* [Emphasis added.]

In summary, NIOSH calculated internal doses for exposure to plutonium/americium using IMBA and the missed dose methods (i.e., based on one-half the MDA value of chest count data) for the employment period of [redact], through [redact]. For the [redact] employment period, internal doses were based on the coworker model using guidance provided in ORAUT-TKBS-0011-5, Table D-6, which states it represents the 95th percentile intake rate. Table 2-12 summarizes the intake rates used by NIOSH.

Table 2-12. Pu/Am Intake Rates Calculated by NIOSH

Radionuclide	Time Period	Calculation Method	Solubility Type	Intake Rate (dpm/day)
Pu-238	[redact]–[redact]	Missed Dose	Super S	1.387
Pu-238	[redact]–[redact]	Coworker Model	Super S	10.058
Pu-239	[redact]–[redact]	Missed Dose	Super S	57.780
Pu-239	[redact]–[redact]	Coworker Model	Super S	419.000
Pu-241	[redact]–[redact]	Missed Dose	Super S	327.614
Pu-241	[redact]–[redact]	Coworker Model	Super S	2,375.728
Am-241	[redact]–[redact]	Missed Dose	M	2.788

Using these data, NIOSH calculated a <u>missed</u> plutonium dose of 5.038 rem, a <u>coworker</u> plutonium dose of 40.502 rem, and a <u>missed</u> americium dose of 0.493. Annual missed plutonium and americium internal dose values were entered into IREP as the mode of a triangular dose distribution. Coworker plutonium doses were entered as a constant value with no uncertainty.

<u>SC&A's 'Method A'</u>

SC&A's 'Method A' calculated plutonium/americium intakes by comparing the plutonium urine and chest count results and the americium urine and chest count results. A chronic intake was assumed to have occurred throughout the EE's first employment period, [redact] to [redact]. The level of the intake was based on one-half the MDA of the analysis.

Using IMBA and a maximum likelihood fitting method, the total plutonium intake rate was determined for Type S plutonium, based on both the urine and chest count data. Following the same method, the americium urine and chest count data were used to determine the Type S americium intake rate. The RFP Pu-Am Intake Calculation tool was used to determine the isotopic mixture for weapons-grade plutonium with Pu-241 weight percent of 0.36%.

Table 2-13 shows the individual plutonium and americium intake rates based on the plutonium urine and chest count data. SC&A's 'Method A' noted that the Am-241 intake rate derived using the urine data was consistent with the intake rate derived using the chest count data.

Table 2-13. Pu/Am Chronic Intakes ([redact]–[redact]) Derived by SC&A's 'Method A'

Radionuclide	Solubility Type	Intake Rate (dpm/day)
Pu-238	S	2.5
Pu-239/240	S	104.5
Pu-241	S	592.5
Am-241	S	5.04

Using the chronic annual dose workbook (CADW), annual doses were calculated from each of the above chronic intakes. To account for intakes of plutonium strongly retained in the lung (Type SS), the methods described in Section 4.0 of ORAUT-OTIB-0049 and Attachment D were used to modify the plutonium and americium doses derived using CADW based on a 5-year chronic intake. Table 2-14 shows the isotopic doses from CADW, the dose adjustment, the chest count adjustment factors from Attachment D, yearly fraction to account for partial year exposure in [redact] and [redact] (since CADW only calculates whole-year doses), and the total adjusted dose.

All alpha doses were entered into IREP as a geometric mean (GM) value of a lognormal distribution with a GSD of 3.0.

Table 2-14. SC&A's 'Method A' OTIB-0049 Adjusted Doses

	Isotopic Dose (rem)				Total Dose (rem)	Dose Adj. Factor	OTIB-49 Adj. Dose	*Chest Count Adj. Factor	Annual Adj. Dose	Frac. of Year	Total Adj. Dose (rem)
	Pu-239	Pu-238	Pu-241	Am-241							
[redact]	1.408E+00	3.891E-02	1.918E-03	7.821E-02	1.527	1.6	2.443	2.6	0.9398	0.175	0.165
[redact]	1.844E+00	5.045E-02	5.079E-03	1.015E-01	2.001	1.9	3.803	2.6	1.4625	1.000	1.463
[redact]	2.055E+00	5.586E-02	9.050E-03	1.124E-01	2.232	2.1	4.688	2.6	1.8031	1.000	1.803
[redact]	2.210E+00	5.978E-02	1.329E-02	1.204E-01	2.403	2.4	5.767	2.6	2.2182	1.000	2.218
[redact]	2.325E+00	6.269E-02	1.741E-02	1.265E-01	2.532	2.6	6.582	2.6	2.5316	1.000	2.532
[redact]	2.417E+00	6.499E-02	2.125E-02	1.312E-01	2.634	3.5	9.219	2.6	3.5458	0.532	1.885
[redact]	1.075E+00	2.771E-02	2.284E-02	5.639E-02	1.181	4.5	5.317	2.6	2.0448	0.625	1.277
[redact]	6.966E-01	1.761E-02	2.290E-02	3.617E-02	0.773	5.7	4.408	2.6	1.6954	1.000	1.695
[redact]	5.286E-01	1.324E-02	2.190E-02	2.740E-02	0.591	6.9	4.079	2.6	1.5688	1.000	1.569
[redact]	4.117E-01	1.023E-02	2.040E-02	2.130E-02	0.464	8.2	3.802	2.6	1.4622	1.000	1.462
[redact]	3.289E-01	8.109E-03	1.883E-02	1.698E-02	0.373	9.6	3.579	2.6	1.3764	1.000	1.376
[redact]	2.697E-01	6.598E-03	1.740E-02	1.391E-02	0.308	11	3.384	2.6	1.3016	1.000	1.302
[redact]	2.266E-01	5.494E-03	1.617E-02	1.166E-02	0.260	12	3.119	2.6	1.1995	1.000	1.200
[redact]	1.942E-01	4.672E-03	1.511E-02	9.985E-03	0.224	13	2.912	2.6	1.1200	1.000	1.120
[redact]	1.693E-01	4.039E-03	1.420E-02	8.692E-03	0.196	15	2.944	2.6	1.1323	1.000	1.132
[redact]	1.499E-01	3.546E-03	1.342E-02	7.685E-03	0.175	16	2.792	2.6	1.0739	1.000	1.074
[redact]	1.342E-01	3.151E-03	1.274E-02	6.871E-03	0.157	17	2.668	2.6	1.0263	1.000	1.026
[redact]	1.212E-01	2.822E-03	1.212E-02	6.199E-03	0.142	18	2.562	2.6	0.9855	1.000	0.986
[redact]	1.102E-01	2.546E-03	1.154E-02	5.625E-03	0.130	20	2.598	2.6	0.9991	1.000	0.999
[redact]	1.007E-01	2.309E-03	1.101E-02	5.136E-03	0.119	21	2.503	2.6	0.9625	1.000	0.963
[redact]	9.248E-02	2.104E-03	1.050E-02	4.710E-03	0.110	23	2.525	2.6	0.9712	1.000	0.971
[redact]	8.513E-02	1.921E-03	1.001E-02	4.329E-03	0.101	24	2.434	2.6	0.9360	1.000	0.936
[redact]	7.851E-02	1.758E-03	9.535E-03	3.988E-03	0.094	26	2.439	2.6	0.9379	1.000	0.938
[redact]	7.257E-02	1.613E-03	9.076E-03	3.681E-03	0.087	27	2.347	2.6	0.9028	1.000	0.903
[redact]	6.719E-02	1.481E-03	8.635E-03	3.405E-03	0.081	29	2.341	2.6	0.9002	1.000	0.900
[redact]	6.226E-02	1.361E-03	8.203E-03	3.150E-03	0.075	31	2.324	2.6	0.8939	1.000	0.894
[redact]	5.770E-02	1.251E-03	7.782E-03	2.917E-03	0.070	33	2.298	2.6	0.8840	1.000	0.884
[redact]	5.355E-02	1.151E-03	7.378E-03	2.705E-03	0.065	35	2.267	2.6	0.8720	1.000	0.872

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Table 2-14. SC&A's 'Method A' OTIB-0049 Adjusted Doses

	Isotopic Dose (rem)				Total Dose (rem)	Dose Adj. Factor	OTIB-49 Adj. Dose	*Chest Count Adj. Factor	Annual Adj. Dose	Frac. of Year	Total Adj. Dose (rem)
	Pu-239	Pu-238	Pu-241	Am-241							
[redact]	4.974E-02	1.061E-03	6.991E-03	2.508E-03	0.060	37	2.231	2.6	0.8581	1.000	0.858
[redact]	4.622E-02	9.774E-04	6.617E-03	2.327E-03	0.056	39	2.189	2.6	0.8421	1.000	0.842
[redact]	4.294E-02	9.006E-04	6.255E-03	2.161E-03	0.052	41	2.142	2.6	0.8240	1.000	0.824
[redact]	3.994E-02	8.312E-04	5.912E-03	2.007E-03	0.049	43	2.094	2.6	0.8052	1.000	0.805
[redact]	3.718E-02	7.674E-04	5.586E-03	1.866E-03	0.045	46	2.088	2.6	0.8032	1.000	0.803
											38.676

SC&A's 'Method B'

SC&A's 'Method B' performed internal dose assessments using results from the urinalyses and lung count monitoring methods. A comparison of these results was made, and the doses that were considered the most scientifically sound and claimant favorable, as described below, were used to determine the POC.

Missed Plutonium Dose Based on Urinalyses Data. SC&A's 'Method B' first assessed missed plutonium dose based on urinalyses results, which were all below the MDA value. Intakes were calculated based on one-half the MDA value of 0.24 dpm/24 hours, as specified in Table 5-5 of ORAUT-TKBS-0011-5 and the isotopic fractions of alpha activity in weapons-grade plutonium listed in Table 5-1 of ORAUT-TKBS-0011-5. A chronic inhalation of Type S plutonium was calculated using the last plutonium bioassay on [redact]. In order to account for Type SS plutonium, the Pu-239 results were multiplied by 4. Table 2-15 shows resultant intakes and dose.

Table 2-15. Plutonium Intakes and Doses Calculated from Bioassay Results

Isotope	Absorption Type	Fraction of Weapons Grade Pu (WGP)	Excreted bioassay rate (dpm/24 hr)	Intake (dpm/d)	Dose (rem)
Pu-238	Type S	0.023	0.0028	10.72	2.24
Pu-239	Type SS	0.8	0.098	369	280
Pu-240	Type S	0.18	0.022	82.88	15.8
				Total =	298.04

Missed Plutonium Dose Based on Lung Count Data. SC&A's 'Method B' chose to assign missed dose using the lung count taken on [redact], which measured exposure to Am-241 using a highly sensitive Phoswich detector with a high americium MDA. Table B-11 of ORAUT-TKBS-0011-5 lists the MDA values for Am-241 of 0.21 nCi, given the type of detector and the conditions in which the test was performed. The concentration of americium in units of parts per million (ppm) was used to determine the associated MDA of plutonium for the lung counts, based on guidance in Attachment B, Table B-9, of ORAUT-TKBS-0011-5. Table B-9 recommends multiplying the americium MDA by 20.7 in order to get the MDA for plutonium. This resulted in a Pu-239+240 MDA of 4.347 nCi. Using ½ MDA value for plutonium and the isotopic fractions of alpha activity in weapons-grade plutonium listed in Table 5-1 of ORAUT-TKBS-0011-5, the IMBA program was used to derive the intakes and doses shown in Table 2-16.

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Table 2-16. Type S Plutonium Intakes and Doses from Lung Counts Calculated by SC&A's 'Method B'

Isotope	Absorption Type	Fraction of WGP	Lung Count Measurement of ½ MDA (pCi)	Intake (pCi/d)	Dose (rem)
Pu-238	Type S	0.023	51	1.528	0.709
Pu-239	Type S	0.8	1774	52.44	22.1
Pu-240	Type S	0.18	399	11.77	4.98

To account for exposure to Super S highly insoluble plutonium, the annual doses from lung counts were multiplied by adjustment factors, which are dependent upon the number of years that the individual was exposed. Therefore, the adjustment factors from Table D-1, page 46 of ORAUT-OTIB-0049, from the chronic [redact] years column were applied. This resulted in a total lung dose of 55.650 rem.

After comparing the urinalyses data and lung count data, SC&A's 'Method B' decided that, even though the resultant doses were lower, the lung count data represented a more direct bioassay method. Therefore, the lung count results for plutonium were entered into IREP in order to determine the POC.

<u>Missed Americium Dose Based on Urinalyses Data</u>. All urinalyses results for americium were below the MDA of 0.31 dpm/24hour (ORAUT-TKBS-0011-5, Table 5-6). Using ½ MDA value and assuming a chronic inhalation of Type S Am-241, IMBA was used to calculate an intake of 12.87 dpm/d, which resulted in 2.730 rem to the lung.

<u>Missed Americium Dose Based on Lung Count Data</u>. As with the plutonium dose, SC&A's 'Method B' chose to assign missed dose using the lung count taken on [redact]. The lung count MDA for americium is 0.21 nCi (ORAUT-TKBS-0011-5, Table 5-11). A chronic intake of 3.11 pCi/d was calculated by the IMBA program using the ½ MDA value. Using this intake, the total lung dose from exposure to americium from the beginning of employment to the date of diagnosis is 1.464 rem.

After comparing the urinalyses data and lung count data, SC&A's 'Method B' decided that, even though the resultant doses were lower, the lung count data represented a more direct bioassay method. Therefore, the lung count results for americium were entered into IREP in order to determine the POC.

2.2.2 Tritium Dose

All three DR methods assessed potential dose associated with exposure to tritium. The EE was monitored for tritium during the first employment period via three urinalyses samples. All results were reported as less than MDA.

Using guidance in ORAUT-TKBS-0011-5, ½ MDA value, and IMBA, all three DR methods calculated a chronic tritium intake for the time period of [redact]–[redact], which resulted in a total dose <0.001 rem. Therefore, the doses from the tritium intakes were not included in the IREP input.

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2.2.3 Depleted Uranium Dose

Only SC&A's 'Method B' assumed that the EE may have been exposed to DU while at RFP. 'Method B' did determine, however, that the EE would not have had exposure to thorium. Therefore, the TBD was reviewed to identify time periods and locations where the EE worked and thorium exposures were not plausible, but exposures to DU were plausible.

Missed dose from exposure to DU was calculated using the MDA of the lung count data. Section 5.3.2.2.2 of ORAUT-TKBS-0011-5 states the following regarding the uranium MDA for lung counts:

> *U-238 worker-specific MDA can be obtained by multiplying the Am-241 worker-specific MDA by 9.4. That result is divided by 0.89 to obtain the worker-specific MDA for DU.*

The Am-241 MDA of 0.21 nCi was used in 'Method B's' assessment, based on the count performed on [redact]. One-half the MDA value was multiplied by the alpha activity fractions for DU listed in Table 5-4 of ORAUT-TKBS-0011-5. The DU daily intake rates derived using these MDA values in the IMBA program were as follows: 3.25 pCi/d of U-234, 0.44 pCi/d of U-235, and 29.26 pCi/d of U-238. Using these intakes in the IMBA program and assuming a chronic intake from the beginning to the end of employment produced a total missed dose to the lung from DU of 10.300 rem.

All alpha doses calculated by SC&A's 'Method B' were entered into IREP as a mean of a normal distribution with an uncertainty of 30%.

<u>Summary of Assigned Internal Doses</u>

A summary of the total internal dose assigned by each DR method for the EE's employment at RFP is provided in Table 2-17.

Table 2-17. Comparison of RFP Total Internal Doses

Radionuclide	NIOSH (rem)	SC&A-Method A (rem)	SC&A-Method B (rem)
Plutonium/Americium	46.033	38.676	57.114
Depleted Uranium	Not considered	Not considered	10.300
Total	46.033	38.676	67.414

Although all three DR methods used guidance in ORAUT-TKBS-0011-5 and compared all applicable solubility types, including Type Super S, differences in doses resulted from NIOSH using coworker data for the majority of their internal dose, while SC&A's 'Method A' and 'Method B' based their doses on missed chest count data. In addition, SC&A's 'Method B' assigned dose from DU, which was not considered by NIOSH and SC&A's 'Method A.'

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3.0 SUMMARY CONCLUSIONS

Total external and internal doses and resultant POCs calculated by SC&A 'Method A,' SC&A 'Method B,' and NIOSH in behalf of Case #[redacted] are presented in Table 3-1 for comparison.

Table 3-1. Comparison of Total External and Internal Doses Estimated for the Lung

Total Lung Doses	NIOSH (rem)	SC&A-Method A (rem)	SC&A-Method B (rem)
External Doses:			
- Photons <30 keV	0.030	0.019	0.030
- Photons 30-250 keV	1.562	1.488	2.254
- Neutrons <10 keV	0.118	0.129	0.174
- Neutrons 10-100 keV	0.036	0.027	0.037
- Neutrons 0.1-2 MeV	1.037	0.882	1.196
- Neutrons 2-20 MeV	0.457	0.400	0.545
Occupational Medical Dose	0.084	0.294	0.294
Internal Doses:			
- Alpha	46.033	38.676	67.414
Total Lung Dose	**49.357**	**47.915**	**71.944**
POC	**47.51%**	**56.71%**	**55.75%**

As shown in Table 3-1, internal doses contributed the majority of total dose assigned by each of the DR methods. The most striking element of this comparison is that although SC&A's 'Method A' derived a total dose that is nearly 1.5 rem less than NIOSH's total dose, the resultant POC was higher than the POC reported by NIOSH and would have resulted in a compensable claim. Additionally, SC&A's DR 'Method B' assigned doses that were 1.5 times higher than SC&A's 'Method A;' however, 'Method B's' resultant POC was nearly identical to the SC&A's 'Method A' POC. This difference in POC is primarily due to how uncertainty was defined in IREP. A more detailed discussion of uncertainty, as well as variables that contributed to key differences in dose assignments, is presented below.

- Dose Reconstruction Methodology
  - NIOSH and SC&A's 'Method B' employed a best-estimate approach to dose reconstruction.
  - SC&A's 'Method A' employed a modestly minimizing approach to reconstructing doses.

- Assignment of Unmonitored Dose
  - NIOSH assigned unmonitored dose using the 50th percentile coworker values for a total of 6.51 months.
  - SC&A's 'Method B' calculated unmonitored dose based on the 95th percentile of coworker data for 15.1 months.
  - SC&A's 'Method A' did not assign unmonitored dose.

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- <u>Assignment of Occupational Medical Dose</u>
  - NIOSH assigned medical doses for only 2 <u>documented</u> x-ray exams, based on values cited in the RFP TBD.
  - SC&A's 'Method A' and 'Method B' assigned <u>annual</u> occupational medical x-ray exams based on dose values in the RFP TBD.

- <u>Assignment of Internal Doses</u>
  - NIOSH assigned internal doses from monitored bioassays, which were all <MDA, using two methods: (1) 1st monitoring period ([redact]–[redact]) doses were based on <u>missed dose approach</u> (i.e., ½ MDA value for chest count data), and (2) 2nd monitoring period ([redact]–[redact]) doses were based on <u>coworker model</u>.
  - SC&A's 'Method A' and 'Method B' assigned coworker internal doses for both monitoring periods based on a <u>missed dose method</u> (< ½ MDA) using chest count data.

- <u>Dose Uncertainty Entered into IREP</u>
  - NIOSH assigned internal coworker doses, which represent 82% of the total dose, as a <u>constant value</u> with no uncertainty.
  - SC&A's 'Method A' assigned internal missed doses, which represented 80% of the total dose, as a GM of a <u>lognormal distribution</u> with a GSD of 3.0.
  - SC&A's 'Method B' assigned internal missed doses, which represent 93% of the total dose, as a mean of a <u>normal distribution</u> with an SD of 30%.

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4.0 REFERENCES

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