Draft

ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

SC&A'S EVALUATION OF NIOSH'S WHITE PAPER, "REASSESSMENT OF INTERNAL RADIATION DOSE FROM SOURCES AT THE ROCKY FLATS PLANT CRITICAL MASS LABORATORY," OF NOVEMBER 28, 2016

Contract No. 211-2014-58081
SCA-TR-2017-SEC003, Revision 0

Prepared by

Ron Buchanan, PhD, CHP

SC&A, Inc.
1608 Spring Hill Road, Suite 400
Vienna, Virginia, 22182

Saliant, Inc.
5579 Catholic Church Road
Jefferson, Maryland 21755

January 2017

SC&A, INC.: ***Technical Support for the Advisory Board on Radiation and Worker Health Review of NIOSH Dose Reconstruction Program***

DOCUMENT TITLE:	SC&A's Evaluation of NIOSH's White Paper, "Reassessment of Internal Radiation Dose from Sources at the Rocky Flats Plant Critical Mass Laboratory," of November 28, 2016
DOCUMENT NUMBER/ DESCRIPTION:	SCA-TR-2017-SEC003
REVISION NO.:	0 (Draft)
SUPERSEDES:	N/A
EFFECTIVE DATE:	January 24, 2017
TASK MANAGER:	Joe Fitzgerald [signature on file]
PROJECT MANAGER:	John Stiver, MS, CHP [signature on file]
DOCUMENT REVIEWER(S):	John Stiver, MS, CHP [signature on file]

Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	01/24/2017	Initial issue

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

CML	Critical Mass Laboratory
Cs	cesium
DOE	U.S. Department of Energy
dpm	disintegrations per minute
f	intake fraction
HEU	high-enriched uranium
IMBA	Integrated Modules for Bioassay Analysis
MFAP	mixed fission and activation products
mrem	millirem
µCi	microcurie
µCi/g	microcuries per gram
mW	milliwatt
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
RFP	Rocky Flats Plant
Sr	strontium

1.0 INTRODUCTION AND BACKGROUND

In March 2016, representatives from the National Institute for Occupational Safety and Health (NIOSH) and SC&A, Inc. evaluated documents stored at the Los Alamos National Laboratory from the former Critical Mass Laboratory (CML) located at the Rocky Flat Plant (RFP), Golden, Colorado. In November 2016, NIOSH issued *Reassessment of Internal Radiation Dose from Sources at the Rocky Flats Plant Critical Mass Laboratory: White Paper* (NIOSH 2016), which evaluated the potential mixed fission and activation products (MFAP) exposure at the RFP CML. The following sections contain SC&A's evaluation of NIOSH's report.

2.0 OUTLINE OF NIOSH'S REPORT

To facility the evaluation of NIOSH's report (NIOSH 2016), SC&A outlines the main sections of the report, as follows:

- **Purpose** (page 2): The purpose of the report was to reevaluate potential MFAP exposures at the CML because, according to the report:

  > *A publicly released document* [NIOSH 2015] *citing a maximum reactor operating power of 10 milliwatts (mW) and typical experiment duration of one hour were previously used to estimate the MFAP inventory built up over time in high-enriched uranium (HEU) solution fuel used in CML experiments….*
  >
  > *In the earlier assessment, internal doses from the estimated MFAP inventory were bounded by assuming removable surface contamination from dried solution spills to be at the limit for a posted Contamination Area. The average air concentration of respirable particles was then estimated by applying a resuspension factor. Recently captured documents contain air monitoring results, surface contamination measurements, more-accurate power estimates based on carefully measured gamma photon emissions from the irradiated fuel, records of experiment duration, and neutron flux profiles. This information provides data against which the prior assumptions can be re-evaluated.*

- **Exposure Concerns** (page 2): CML personnel were monitored for alpha-emitting radionuclides but not routinely for MFAP. Additionally, surfaces and equipment were routinely monitored for alpha contamination, but not for MFAP contamination.

- **History of Criticality Experiments** (pages 3 and 4): A total of 778 subcritical and critical experiments were conducted from May 1967 through October 1987.

- **Thermal Power and Fission Rates** (pages 5–8): Several methods of estimating the thermal power and fission rates are provided in this section. The experiment that was reported to the Energy Research and Development Administration on June 3, 1977 (and produced the greatest number of fissions), had an average power of 6.7 mW with an experiment time of 70.5 minutes (compared to 10 mW for 1 hour as previously used).

- **CML Surface Alpha Contamination** (pages 8–20): According to pages 8–9 of NIOSH's report (NIOSH 2016):

  > *Internal doses from the estimated MFAP inventory were bounded in the earlier estimate by assuming that removable surface contamination from dried solution spills was evenly dispersed over CML surfaces at the DOE* [U.S. Department of Energy] *limit (1,000 dpm* [disintegrations per minute]*/100 cm^2) for a posted Contamination Area. The average air concentration of respirable particles was then estimated by applying a resuspension factor. Recently captured documents contain both air monitoring and surface contamination measurement results against which the prior assumptions can be reevaluated.*

  Information on pages 8–20 provides examples of alpha contamination survey results during the 1980s at the CML. Note that these results are for alpha activity, not MFAP activity (MFAP would consist of mainly beta/gamma emitters). This section is included in NIOSH's report to support the following statements on page 20:

  > *Surveys for removable alpha contamination at CML were conducted regularly. Excursions above the applicable DOE limits (20 dpm/100 cm^2 in uncontrolled office areas and 1,000 dpm/100 cm^2 in controlled-access experimental areas) were confined to discrete areas and were quickly decontaminated below the limits….*
  >
  > *In light of the above information, the assumption that average removable contamination available for resuspension in the experimental and material storage areas (Rooms 101, 102, and 103) was equal to or less than the Contamination Area limit of 1,000 dpm/100 cm^2 is claimant-favorable.*

- **CML Workplace Air Alpha Monitoring** (pages 20–29): According to page 20 of NIOSH's report:

  > *Bounds on internal dose from MFAP were previously based on airborne concentrations calculated by applying a resuspension factor to surface contamination limits posted for the facility….*
  >
  > *NIOSH has since captured formal plant-wide procedures describing a particulate air monitoring program during the period from 1980-1989 for alpha-particle emissions from uranium, plutonium, and americium at sampling locations selected by process knowledge or professional judgment. Additional captured documents indicate that these procedures appear to have been followed and that routine alpha air monitoring was performed at the CML during the period 1980-1989.*

  This section of NIOSH's report presents air sampling results for alpha activity during the 1980s at the CML. The purpose of this information is to derive the bounding value of alpha activity in air of **13.5 dpm/m^3**, as show on page 29 of the report. This value was then used on page 35 to derive the radionuclide intake fraction (*f*) from the fuel mixture of 1.5×10^{-7}, which was used later on page 35 of NIOSH's report to determine the MFAP intakes from the fuel mixture.

- **Assessment of Unmonitored Dose from MFAP** (pages 30–35): NIOSH estimated the potential MFAP intake and doses at CML using the following procedure:

  1. **MFAP inventory** (pages 30–32): NIOSH used a combination of the computer programs SCALE, TRITON, and ORIGEN-S to derive a list of MFAP and associated activities resulting from a typical critical experiment lasting 70.5 minutes at an average power level of 6.7 mW.

  2. **Radionuclide selection** (pages 33–34): NIOSH used methods from ORAUT-OTIB-0054, Revision 03, *Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses*, to select the dosimetrically-significant radionuclides from the MFAP inventory. These 36 radionuclides and their activities (in becquerels) are listed in Table 9, page 34, of NIOSH's report.

  3. **Activity intake fraction** (page 35): NIOSH used the following assumptions to estimate the potential intake fraction from the fuel mixture:

     - The HEU contained 70 microcuries per gram (µCi/g) of alpha activity (SC&A verified that this value is consistent with other DOE sites that handled enriched uranium).

     - There were 2,783 grams of HEU in the experimental tank (using a tank of 27.92 cm in diameter and filled to a height of 31.2 cm with a fuel solution of density of 145.68 g/L, which is approximately the middle value of 10 RFP experiments as described in Palmer 2004, Table 6, page 8.

     - Using these parameters, there was a total of 1.95E3 µCi of alpha activity in the fuel (i.e., 70 µCi/g x 2,783 g = 1.95E3 µCi).

     - After the experiment, it was assumed that the relative ratios of the alpha-emitting radionuclides were the same in the fuel, surface contamination, and air (i.e., there were no situations or processes that selected or concentrated certain radionuclides). The same assumption was applied to the MFAP radionuclides.

     - The bounding measured alpha activity was 13.5 dpm/m^3.

     - Over a 2-year period (as used in ORAUT-OTIB-0054) the potential intake would be 0.0292 µCi of alpha activity (i.e., 13.5 dpm/m^3 × 1.2 m^3/hr × 2000 hr/y × 2y × 4.5E-7 µCi/dpm = 0.0292 µCi).

     - The alpha intake fraction (*f*) would be:

       $$f = [0.0291\ \mu Ci]/[1.95E3\ \mu Ci] = 1.5E\text{-}7.$$

- This intake fraction would also apply to MFAP present in the fuel.

4. **MFAP intakes** (page 35): The MFAP radionuclide activities in Table 9 were multiplied by the derived intake fraction value of 1.5E-7 to obtain the potential MFAP intakes.

5. **Maximum dose** (page 35): The 50-year committed organ doses were derived and summed over the 36 MFAP radionuclides listed in Table 9 for solubility Types F, M, and S for 25 individual organs. The resulting maximum organ doses for the three solubility types are listed in Table 10. The largest dose, 2.5E-9 sievert (2.5E-4 mrem) would be to the bone surface from Type F solubility MFAP over a 50-year period.

3.0 SC&A'S EVALUATION

SC&A evaluated NIOSH's methodology, assumptions, and parameters and verified the calculations, some of which are illustrated in Section 2.0 of this report. Additionally, SC&A verified some of the important references that NIOSH used in its analyses. SC&A did not rerun the computer simulation programs (SCALE, etc.) or the 36 radionuclide doses to 25 organs because this would have required considerable additional resources. SC&A did verify that the radionuclides and their relative activities listed in Table 9 (NIOSH 2016) were reasonable compared to the MFAP listed in Table 7a of ORAUT-OTIB-0054. SC&A also performed Integrated Modules for Bioassay Analysis (IMBA) runs for some of the most dose-significant radionuclides (with their associated activities from Table 9, modified by the intake fraction of 1.5E-7) for solubility Types F, M, and S and arrived at total 50-year committed organ doses of much less than 0.001 rem, which concurs with NIOSH's results in Table 10 of the white paper (NIOSH 2016). Additionally, SC&A ran the ORAUT-OTIB-0054 workbook program using strontium-90 (Sr-90) (and also cesium-137 [Cs-137]) as the indicating radionuclide (with the Sr-90 or Cs-137 radionuclide activities as listed in Table 9, modified by the intake fraction of 1.5E-7) to determine potential MFAP organ doses from typical reactor fuels with 180-day decay (as listed in Table 7a of ORAUT-OTIB-0054) and derived 50-year committed organ doses that were much less than 0.001 rem, which also concurs with NIOSH's results.

4.0 SUMMARY AND CONCLUSIONS

SC&A's evaluation of NIOSH's methodology indicates that NIOSH used reasonable and claimant-favorable assumptions and parameters in deriving the potential MFAP intakes and doses for CML workers at the RFP. SC&A did not identify any outstanding errors in the calculations or any data issues in NIOSH's process. Various parameters and scenarios could be used to estimate the potential MFAP intakes at the CML, with differing results. However, as indicative of the very small MFAP doses derived by both NIOSH and SC&A, even a change of a factor of 10 or 100 in the results would not alter the conclusions that the potential doses from MFAP were very small, and much less than 1 mrem, the minimum dose used in dose reconstruction.

5.0 REFERENCES

NIOSH 2015. *Assessment of Sealed Radioactive Sources, and Fission and Activation Products as Radiological Exposure Sources in the Rocky Flats Plant Critical Mass Laboratory (Building 886 Cluster): White Paper*, Revision 0, National Institute for Occupational Safety and Health, Division of Compensation Analysis and Support, Cincinnati, Ohio. June 9, 2015.

NIOSH 2016. *Reassessment of Internal Radiation Dose from Sources at the Rocky Flats Plant Critical Mass Laboratory: White Paper*, Revision 0, National Institute for Occupational Safety and Health, Division of Compensation Analysis and Support, Cincinnati, Ohio. November 28, 2016.

ORAUT-OTIB-0054. 2015. *Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses*, Revision 03, Oak Ridge Associated Universities, Cincinnati, Ohio. February 6, 2015.

Palmer 2004, *Minimally Reflected Cylinders of Highly Enriched Solutions of Uranyl Nitrate,* NEA/NSC/DOC(95)03/II, Volume II, HEU-SOL-THERM-001, from the *International Handbook of Evaluated Criticality Safety Benchmark Experiments*, Brian Palmer, Idaho Chemical Processing Plant. September 30, 2004. [SRDB Ref. ID 142464]