Draft Responses to SC&A's Review of Addendum 3 to the NIOSH Savannah River Site Special Exposure Cohort (SEC-00103) EVALUATION REPORT

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Finding 1*: NIOSH has characterized various thorium storage and processing activities in its latest Addendum to the Evaluation Report (NIOSH 2012). However, NIOSH's catalog of places and times where such activities were carried out is not complete. A more complete description of the source term is needed for scientifically reasonable thorium dose reconstruction by the methods proposed by NIOSH.*

Response: The list of processing and storage activities listed in Addendum 3 was derived from examination of every thorium inventory record available from 1973. The last campaign to irradiate Th-232 ended in 1970 with some of that thorium being transferred to Fernald. The balance was transferred to waste tank #15 in the tank farm (SRDB Ref ID 105024). Small amounts of solid waste from target manufacturing and the Savannah River Laboratory (SRL) were sent to 643-E (Old Burial Ground) and 643-7E (New Burial Ground). Thorium was used in 235-F in the late 1970s through 1981 as a surrogate for plutonium and is discussed in Addendum 3. Thoria spheres were fabricated in Building 235-F in 1977 for use as a stand-in for plutonium. The spheres were about an inch in diameter (about 300 grams of thorium in each). NIOSH assumes SRS made about 12 of these spheres using about 3.5 kg. The quantity of Th-232 in 235-F was 0.9 kg (0.09 mCi) in early 1977, increasing to 4 kg (0.4 mCi) remaining fairly constant through 1998 when thorium was removed from the building.

In support of the alternate fuels program from 1977 through early 1980, some thorium was used at SRL for dissolution studies. SRS procured irradiated thorium from Elk River for dissolution testing. That work was conducted in high-level caves using a total of 35 kg (3.5 mCi). SRS procured about 35 kg non-irradiated thorium from Nuclear Fuel Services and 8 kg non-irradiated thorium from Bettis Lab for dissolution studies. They also received a small amount of Th-232 from General Atomics in the form of microspheres. That work was done in vented hoods in Building 773-A using small pellets (3 to 4) of about 22 grams each (22 µCi). Several experiments were performed over a few months. Pellets were double bagged before being brought in and out of the hood. This work was done on a laboratory scale basis. A total of four people performed these analyses, two chemists and two technicians. Some of this work is

documented in SRS documents DP-1590, DP-1605, and DP-MS-80-11X. SRS procured thirty thorium fuel rods in fuel assemblies from Hanford in late 1979 to irradiate and perform further dissolution studies. All thirty rods were stored in a cage in 773A, room C 070. One of the assemblies was tested for six months at the long term flow test facility at CMX. At the end of the test neither the assembly nor the rods showed any noticeable wear or corrosion damage. The alternate fuels program was cancelled in 1980 before any of the Hanford rods were irradiated. Addendum 3 stated that the fuel rods were buried but, with the discovery of additional information, NIOSH now understands that most of the Hanford fuel was returned in 1981. The fuel rods from Hanford were sent to the SRS burial ground for disposal. NIOSH has documentation to show an additional 46 kg of Th-232 from 773-A were buried between 1982 and 1983 (SRDB Ref ID's 114005, 113976, 113977). Increased and decreased inventories of Th-232 in Building 773-A, consistent with these studies, are shown in Table 5-2 of Addendum 3. The inventories given for Building 773-A Chem Stores declined slightly each year between 1981 and 1985, indicating some use of small amounts of thorium nitrate in laboratories. By procedure SRS did not require accounting for laboratory use of thorium nitrate when the total unaccounted for weight was less than 6 kg in a year (SRDB Ref ID 108716). In 1985 an additional 12.4 kg Th-232 was transferred from 773-A to the burial ground (SRDB Ref ID 113968).

In 1989, SRS began obtaining additional thorium for use at Building 773-A ranging from 41.6 kg in 1989 to 208 kg in 1991 with variations in other years. The listed inventory for Th-232 in Building 773-A increased to 286 kg in 2000 and to 399 kg in 2002. By 2004 only 8 kg thorium remained in 773-A, and by 2007 only 4 kg remained. During the years 1989 through as recent as 2004, thorium was used as a surrogate for plutonium and neptunium during design and testing of waste glass and immobilization activities. SRS began using a non-radioactive surrogate by the early 2000s. However, the bulk of thorium (at least 175 kg) remained constant over that time likely indicating that most was in storage.

Apart from thorium used in research and as a surrogate, the majority of thorium inventoried at SRS was stored in the RBOF and in waste tanks and burial area.

Finding 2: *Significant amounts of thorium were involved in some activities, such as using thorium as a surrogate for plutonium-238. NIOSH's argument that the amounts of thorium involved were far smaller than those of other radionuclides is not relevant to the feasibility of thorium dose reconstruction. Thorium-232 exposures need to be considered in their own right at SRS during the 1972–2007 period as they have been at other sites and at SRS during the period prior to October 1, 1972.*

Response: In the response to Finding 1, NIOSH discusses the use of thorium research and surrogate activities. The amount of thorium and activity is small as shown in Table 5-2 of Addendum 3. The maximum activity of thorium-232 (not in waste storage) in a year range from 0.4 millicuries to a maximum of 39.9 millicuries. NIOSH has revised the method to bound potential doses received from exposure to thorium for the period starting January 1, 1990. The methodology is discussed in the response to Finding 27.

Finding 3: *NIOSH's Addendum 3 to the Evaluation Report has not investigated thorium-related incidents beyond mention of the Special Hazards Investigations database, which is known to be incomplete. That database was not designed to be a comprehensive record of incidents. A more detailed investigation of thorium-related incidents appears to be warranted, especially since some of the bioassay data that NIOSH proposes to use is related to trivalent actinide incidents.*

Response: SRS Health Physics documented contamination and exposure incidents in at least three different information systems. Besides documenting certain incidents in the Special Hazards Investigations database, facility specific incident reports as DPSP reports, SRS Health Physics also maintained contamination and exposure events in area log books, in monthly Works Technical Reports, in personal worker files for SRS workers and in company files for subcontractor trades workers. Incident reports are available in DOE claimant files for use in dose reconstruction.

A complete history of all incidents is not necessary given a routine bioassay program. With its long half life, thorium is retained and excreted for long periods following an intake. The assessment of a chronic exposure throughout the use of the material will encompass acute intakes during the time frame.

Finding 4: *NIOSH has not discussed the radon-220 source term derived from the storage of thorium-232. The radon-220 dose could be important in some circumstances where there was significant residual thorium or where thorium was stored in significant amounts. This includes at least two high-level waste tanks.*

Response: As mentioned in the response to Finding 1, thorium liquids were transferred to waste tank #15 in the tank farm (SRDB Ref ID 105024). As of 2011, tank #15 still had the highest inventory of Th-232 – much more than any other tank (SRDB Ref ID 111851). SRS Health Physics also noted that thoron was detected at the H-canyon stack (291-H). SRS Health Physics

routinely monitored for thoron as well as other off-gassed radionuclides. SRS Health Physics noted there were releases of thoron from tank #15 but at a height of ten feet (the ventilation release point). Until 1995 SRS used a limit of 8 DAC-hours but increased the limit as stack concentrations were considered to not be consistent with the concentration of thoron in the breathing zone (SRDB Ref ID 105024). In an interview with former SRS Health Physics staff, they said potential for exposure to thoron was limited to tank #15 (SRDB Ref ID 128804).

Finding 5: *SC&A has concluded that NIOSH's method for comparing the measurements of two sets of workers requires that the monitoring protocols of the two sets of workers were the same. NIOSH has stated that the protocol for CTW bioassays was different. As a result, the method used by NIOSH to compare CTW and NCW Am/Cm/Cf data does not meet the requirements for a valid comparison of the two bioassay datasets for the 1972–1989 period.*

Response: There is no statistical requirement that all workers be on the same monitoring program in order to use the data to develop a coworker model, as long as the monitoring programs adequately characterize all significant intakes. Further, most sites had *graded* monitoring programs where the frequency and types of bioassay performed were based on the likelihood of the workers having a significant intake of radioactive material[1]. Even today this is standard radiation protection practice, so we would expect the bioassay (i.e., sampling) protocols to be different for different groups of workers. Revision 5 of DPSOL 193-302, dated September 1, 1971 (SRDB 124941) specifies bioassay sampling frequencies for Construction Division workers and notes that an annual urine sample was requested from each employee. Specific sampling frequencies are provided for fission products (annual) and plutonium (triennial) and notes that frequencies for other radionuclides are as specified by Health Physics in the Construction Job Plans. These same sampling frequencies were used at least into the 1990s. See SRDB 45958.

Given this, we believe that it is appropriate (for example) to compare intakes calculated from "special" and "task-related" bioassay performed in one group to intakes calculated from "special", "task-related", "routine," and "confirmatory bioassay" in another group.

Finding 6: *NIOSH's coworker model for thorium is based on its conclusion that CTW and NCW bioassay samples are drawn from the same distribution. A corollary of Finding 5 above is that NIOSH's coworker model, which combines NCW and CTW data, is based on an invalid comparison and therefore is not suitable for estimating CTW thorium doses for the 1972–1989 period.*

[1] Graded monitoring is also common in external dosimetry programs.

Response: NIOSH's conclusion is not that CTW and NCW are drawn from the same distribution, but that there is no identifiable difference. The evaluation of stratification in coworker distributions is currently being reviewed by the ABRWH's SEC issued work group.

Finding 7: *The SRS emphasis on incident-related monitoring of CTWs at SRS does not necessarily reflect differences between CTW work and NCW work. As a result, the emphasis on incident-related monitoring may have missed routine exposures for at least some CTW job types.*

Response: The inclusion of workers on an incident driven sampling program would tend to overestimate the true exposures, when used in a coworker study, because samples collected shortly after an intake will contain a larger fraction of the intake than those collected at random times following an acute intake or in the midst of a small chronic intake.

Regardless, this is an instance where basing CTW intakes on the monitoring data for all monitored workers, as recommended by NIOSH, includes monitoring data for workers on routine monitoring programs and also with the potential for routine exposures, rendering the question of whether incident-driven monitoring would detect routine exposures moot.

Finding 8: *The number of CTW data points is less than 30 in each aggregated period during 1984–1989. This is less than the minimum number required for a valid comparison between CTWs and NCWs. Therefore, NIOSH's conclusion that CTW and NCW sample distributions are the same is not valid for this period. As a result, the coworker model based on this conclusion has not been shown to be valid for this period.*

Response: As stated in the response to Finding 5 above, NIOSH's conclusion is not that CTW and NCW are drawn from the same distribution, but that there is no identifiable difference. The use of 30 data points in each period is not a hard and fast limit. The recommendation for a minimum of 30 data points in ORAUT-RPRT-0053 is a recommendation not a requirement. The procedures in ORAUT-RPRT-0053 are only applied by experienced statisticians. Therefore, they are given latitude to exercise professional judgment.

Finding 9: *While NIOSH has not provided disaggregated data for 1981 and 1982, the number of CTW data points for 1982 is less than 30. Hence, the data for 1982 are also insufficient for a CTW-NCW distribution comparison.*

Response: 1981 and 1982 were combined due to the limited data available during this time period. Each year has less data individually than the two years combined. The use of 30 data points in each period is not a hard and fast limit. The recommendation for a minimum of 30 data points in ORAUT-RPRT-0053 is a recommendation, not a requirement. As stated above, the procedures in ORAUT-RPRT-0053 are only used by experienced statisticians. Therefore, they are given latitude to exercise professional judgment.

Finding 10: *Aggregating data over more than 1 year without reference to underlying processes and other data is not justifiable. NIOSH should provide a technical rationale for treating 1981–1982 and 1987–1989 differently than other years. Aggregation over more than 1 year to increase the number of data points is not a suitable technical rationale. If no sound basis can be provided for aggregating data over more than 1 year, NIOSH should do annual aggregating for calculating OPOS values. This is important for evaluating NIOSH's conclusion that CTW and NCW data are drawn from the same distribution. Furthermore, aggregation over multiple years rather than a single year to estimate an OPOS value increases the risk that the result would represent a mix of thorium exposure and Am/Cm/Cf exposure, rendering it scientifically questionable.*

Response: As noted in the response to Finding 1, testing of thorium for use in the alternate fuels program ended in 1980. The only work done with thorium between 1981 and 1989 was as a surrogate and in laboratory analyses, all with small quantities. Given similar processes and source term for thorium, aggregating bioassay data over a 2- or 3-year period is reasonable. The primary sources of exposures were from canyon processing and waste handling but were the same from 1981 through 1989. Given similar processes and source terms for Am/Cm/Cf, aggregating bioassay data over a 2- or 3-year period is reasonable.

Finding 11: *NIOSH has not demonstrated that the number of CTW samples is sufficient to simultaneously maintain low levels of Type 1 and Type 2 errors (for instance, less than 5% for Type 1 errors and less than 15% for Type 2 errors), even in the years when CTWs have more than 30 samples. SC&A's analysis indicates that when the geometric standard deviation (GSD) is much larger than the ratio of CTW to NCW geometric means (GMs), the rate of Type 2 errors will tend to be high. Type 2 errors occur when the null hypothesis (distributions are the same) is incorrectly accepted.*

Response: There are two parts to determining if there is a difference between strata. The first is to determine if there is a statistical difference. The second is to determine if there is a practical difference. When the GSD is much larger than the ratio of the CTW to NCW geometric means, there is no practical difference in small differences between the CTW and NCW geometric means because the small difference is subsumed in the much larger variability inherent in the dataset. This is demonstrated in ORAUT-RPRT-0055 with regard to the difference between CTW and NCW bioassay results for 1985. Therefore, the potential for an increased rate of Type 2 errors when the GSD is much higher than the ratio of the CTW to NCW geometric means is irrelevant since that increase has no practical significance. The evaluation of stratification in coworker distributions is currently being reviewed by the ABRWH's SEC issued work group.

Finding 12: *In some years, the number of data points is inadequate to make a valid comparison between CTWs and NCWs in regard to trivalent actinide data distributions, even when there are*

more than 30 data points. In other cases, there are sufficient data. NIOSH has not analyzed the problem of data adequacy as a function of relative GM and GSD values. Such an analysis is essential for evaluating data adequacy for comparing CTW and NCW distributions.

Response: It is acknowledged that in some years there are not enough data to conduct a comparison. If there were not enough data, a comparison was not performed. For those years where sufficient data were available, a comparison was performed. The process of determining whether to make a comparison for a given year(s) was an analysis of data adequacy. As discussed in the response to Finding 11, there are two parts to determining if there is a difference between strata. The first is to determine if there is a statistical difference. The second is to determine if there is a practical difference. When the GSD is much higher than the ratio of the CTW to NCW geometric means, there is no practical difference in small differences between the CTW and NCW geometric means because the small difference is subsumed in the much larger variability inherent in the dataset. This is demonstrated in ORAUT-RPRT-0055 with regard to the difference between CTW and NCW bioassay results for 1985.

Finding 13: *NIOSH's interpretation of below minimum detectable activity (MDA) results for OPOS calculations is an interpretation of data entry conventions that contains an element of arbitrariness. It is systematically claimant unfavorable when a large fraction of the results are well below the MDA. This finding applies to all cases where NIOSH proposes to use OPOS data as presently calculated for coworker models, including those whose data are reviewed in this report (Am, Cm, Cf and thorium) as well as others, such as neptunium and fission products.*

Response: NUREG-1156, Accuracy and Detection Limits for Bioassay Measurements in Radiation Protection, states in Section 2.5, "Recording of Analytical Results," that:

> The development and formulation of MDA concepts, for the purpose of properly representing, a priori, measurement system capabilities (the assurance of high probabilities of detecting given amounts) should not be misconstrued and misused for purposes of rounding off – and thus biasing – a posteriori measurement results. A result below the stated MDA does not, all-of-a-sudden, lose all information content, just as a result above MDA is not perfectly precise….
>
> Thus, information is present below MDA, so results should be recorded as the best estimate with specifically stated confidence intervals about the estimated mean, even if the mean has a negative value.

The use of values below the MDA, whether for OPOS or for individual samples, avoids the introduction of bias into a statistical analysis. NIOSH's interpretation of below MDA results provides for a more accurate evaluation of the bioassay data than the method proposed by SC&A.

Finding 14: *NIOSH's approach to using data well below the MDA, including negative numbers and zeros to calculate OPOS values, can sometimes yield scientifically meaningless results such as negative OPOS values, implying negative intakes. The problem of negative OPOS results is especially prevalent in the 1983–1989 period.*

Response: As pointed out in footnote 4 of SC&A's review, individual "negative values are not in themselves wrong." Most OPOS values are based on a single bioassay sample. Negative OPOS values are not in themselves wrong as well, whether based on a single bioassay sample or multiple samples. See also the response to Finding 13. While a negative *intake rate* is not *physically* meaningful, a negative *bioassay result* is *scientifically* valid and meaningful. Sampling of an individual with no intakes would be expected to yield a distribution of positive and negative results centered about 0. It is realistic to expect that some routinely monitored individuals had no intakes within a given year and would therefore have some negative results, yielding negative OPOS results in some cases.

Finding 15: *The present NIOSH method of calculating OPOS data would result in systematically very claimant-unfavorable results in the case of the Am, Cm, Cf dataset. This would be true of thorium dose estimates as well as Am, Cm, Cf dose estimates. This is because the vast majority of bioassay results for the 1972–1989 period are well below the MDA.*

Response: As indicated in our response to finding 13, values below the MDA, whether OPOS or for individual samples, avoid the introduction of bias into the statistical analysis. NIOSH's interpretation of below MDA results provides a more precise and accurate evaluation of the bioassay data than the method proposed by SC&A. Because inclusion of results below the MDA is a statistically valid practice, the substitution of the MDA for an actual measured result is not justified because it is claimant favorable. Claimant favorable assumptions are only made in EEOICPA when there are two scenarios which are equally plausible. This is not the case in this instance.

Finding 16: *SC&A is concerned that some reported results in the logbooks that are above the MDA are averages of results that are both well below and well above the MDA. This is much better than the NIOSH OPOS procedure when even below MDA results are used at face value, but it is still a concern since such practices vitiate the connection between the raw data and the workers' intake experience in the real world.*

Response: It is obvious from the data recorded in the laboratory logbooks that the counting data were subject to imprecision. As a result, samples were counted multiple times and the results averaged, a standard practice to reduce uncertainty. This would be expected, given that so many of the results were at or below the MDA.

These practices do not "vitiate the connection between the raw data and the workers' intake experiences in the real world." In fact, they accomplish just the opposite by preserving information and making the best estimate of bioassay results with the available techniques and information.

Finding 17: *NIOSH's coworker data compilation procedure states that chelation-related bioassay samples were excluded from OPOS calculations. However, SC&A found that, contrary to this procedure, chelation-related samples were included in the OPOS averages in every case.*

Response: SC&A's observation is correct. Chelation-related samples were not removed. This statement was erroneously left in from a previous draft version of the document and the related coworker study. While not necessary, use of chelation-related samples as done in the present version of this document would bias the results high and thus be claimant-favorable. The chelation-related samples can be removed in a revision of the document.

Finding 18: *SC&A's examination of the raw data with reported results above the detection limit shows that sometimes the same urine sample, counted in different discs, presents inconsistent results. This indicates that the method used for detection of activity was not always reliable; such widely inconsistent results from the same urine sample cannot be trusted.*

Response: It is obvious from the data recorded in the laboratory logbooks that the counting data were subject to imprecision. As a result, samples were counted multiple times and the results averaged, a standard practice to reduce uncertainty. This would be expected, given that many of the results were near the MDA. Use of the averaging technique implies that the site was aware of the consistency issues and took steps to address it by averaging the results.

Finding 19: *Many reported OPOS values that are above the detection limit are actually the average of negative and positive normalized disc results, or are the average of results with large differences among the different discs derived from the same urine sample. Such average results no longer retain an unambiguous connection to the intake of the worker, do not represent excretion rates of workers, and therefore should not be used to calculate intake rates.*

Response: It is obvious from the data recording methods in the laboratory logbooks that the counting methods used were subject to imprecision. As a result, samples were counted multiple times and the results averaged, a standard practice to reduce uncertainty. This is not remarkable, especially given that so many of the results were at or below the MDA. Use of the averaging technique implies that the site was aware of the consistency issues and took steps to address it by averaging the results.

Finding 20: *Many reported OPOS results below the detection limit are the average of normalized disc results that have a large variation between them. This indicates that the*

resultant average of disc results is highly uncertain. Such average results do not have an unambiguous connection to the intake of workers, do not represent excretion rates, and should not be used to calculate intake rates.

Response: Results less than the MDA will have "widely inconsistent results" because the inconsistency is driven by the statistical variation inherent in measuring small quantities. This fact is the very basis for the concept of an MDA. These practices do not eliminate the connection between the raw data and the workers' intake experiences in the real world. In fact, they accomplish just the opposite by preserving information and making the best estimate of bioassay results with the available techniques and information.

Finding 21: *The number of data points for CTW job types is inadequate to compare relative thorium exposure potential for CTW job types for the 1972–1989 period or to compare the exposure potential of specific CTW job types with NCWs.*

Response: The amount of data available is finite, relatively limited, and not of a nature where additional data can be gathered. There was no intention to compare exposure potential among CTW job types or of specific job types with NCWs.

Finding 22: *Trivalent actinide OPOS results can only be applied in a scientifically defensible way if there is knowledge of whether the worker was exposed to one of the trivalent radionuclides or to thorium. Intake results would not be scientifically credible in the absence of this information.*

Response: Whether to assign thorium dose or that of a specific trivalent radionuclide in this case is similar to the method used for gross alpha results at many sites. In both cases, a single bioassay may be interpreted as detecting one of several different radionuclides or even a combination of multiple radionuclides. The dose reconstructor interprets the bioassay data in a claimant favorable manner based on those radionuclides to which the worker had the potential for exposure. The decision to differentiate between the various radionuclides is made during the course of the dose reconstruction based on information other than the bioassay data itself, such as telephone interview statements, work location, etc. In the present case, if the worker had potential for exposure to thorium but not trivalent radionuclides, then only thorium dose would be assigned, and the converse is also true. If a worker had the potential for exposure to both thorium and trivalent radionuclides, then the dose from all the radionuclides to which he had the potential for exposure would be evaluated and the most claimant favorable assigned.

Finding 23: *NIOSH has not provided evidence that there are data to differentiate between thorium and trivalent actinide exposure. In the absence of such information, it is not possible to establish whether the bioassay data for NCWs and CTWs represent comparable intake conditions.*

Response: Whether to assign thorium dose or that of a specific trivalent radionuclide in this case is similar to the method used for gross alpha results at many sites. In both cases, a single bioassay may be interpreted as detecting one of several different radionuclide or even a combination of multiple radionuclides. The dose reconstructor interprets the bioassay data in a claimant favorable manner based on those radionuclides to which the worker had the potential for exposure. The decision to differentiate between the various radionuclides is made during the course of the dose reconstruction based on information other than the bioassay data itself, such as telephone interview statements, work location, etc. In the present case, if the worker had potential for exposure to thorium but not trivalent radionuclides, then only thorium dose would be assigned, and the converse is also true. If a worker had the potential for exposure to both thorium and trivalent radionuclides, then the dose from all the radionuclides to which he had the potential for exposure would be evaluated and the most claimant favorable assigned.

Finding 24: *Lung doses for trivalent radionuclides, which NIOSH always interprets as Type M, would be far lower than the lung dose when the same bioassay data are interpreted as Type S thorium. Scientifically reasonable dose estimates therefore require knowledge of the time and place of exposure potential to thorium for workers with Am/Cm/Cf bioassay data. NIOSH has not shown that it has the necessary information to interpret the bioassay results as thorium instead of the specific trivalent radionuclide(s) noted in the bioassay record.*

Response: It is not necessary to know the solubility type of the radionuclides(s) to perform the statistical analysis of the bioassay data. Knowledge of the solubility type is used when performing the intake rate calculations for each radionuclide. Trivalent radionuclides, as stated by SC&A, are only evaluated as Type M material. Evaluation of thorium intake rates is beyond the scope of ORAUT-RPRT-0055 but is considered in ORAUT-OTIB-0081. ORAUT-OTIB-0081, Rev 02 contains thorium intake rates for both Type M and S materials. Interpretation of bioassay results when multiple solubility types are possible is always challenging. It has been a long-standing practice to assign the most claimant favorable of the possible solubility types regardless unless sufficient information is available to select or exclude specific solubility types.

Finding 25: *Incorrectly assigning a trivalent radionuclide dose conversion factor to a worker exposed to Type S thorium would yield a very claimant-unfavorable lung and bone dose estimate.*

Response: Whether to assign thorium dose or that of a specific trivalent radionuclide in this case is similar to the method used for gross alpha results at many sites. In both cases, a single bioassay may be interpreted as detecting one of several different radionuclide or even a combination of multiple radionuclides. The dose reconstructor interprets the bioassay data in a claimant favorable manner based on those radionuclides to which the worker had the potential for exposure. The decision to differentiate between the various radionuclides is made during the

course of the dose reconstruction based on information other than the bioassay data itself, such as telephone interview statements, work location, etc. In the present case, if the worker had potential for exposure to thorium but not trivalent radionuclides, then only thorium dose would be assigned, and the converse is also true. If a worker had the potential for exposure to both thorium and trivalent radionuclides, then the dose from all the radionuclides to which he had the potential for exposure would be evaluated and the most claimant favorable assigned. This assignment of the most claimant favorable intake, considering both potential radionuclides to which the worker may have been exposed and the associated solubility types, prevents the assignment of a claimant-unfavorable lung and bone dose estimate.

Finding 26: *Incorrectly assigning a Type S thorium lung dose to a worker exposed to Type M Am, Cm, or Cf would result in a very large and scientifically unwarranted overestimate of the dose. Assigning all intakes to thorium when the exposure was actually to a mixture of the various radionuclides would also overestimate the lung and bone dose.*

Response: Interpretation of bioassay results when multiple solubility types are possible is always challenging. It has been a long-standing practice to assign the most claimant favorable of the possible solubility types regardless unless sufficient information is available to select or exclude specific solubility types. This is true regardless of whether the evaluation concerns only one radionuclide with multiple possible solubility types or multiple radionuclides with different solubilities. As noted in the response to Finding 25, if the worker had potential for exposure to thorium but not trivalent radionuclides, then only thorium dose would be assigned, and vice versa.

Finding 27: *The MDAs for thorium by chest counting in the 1990 Internal Dosimetry document are far higher than the 100 millirem level required to initiate routine monitoring.*

Response: SRS Health Physics monitored all buildings, areas and jobs where work with radioactive materials was used for radioactive contamination. Follow-up monitoring and/or bioassay were performed when there was indication of contamination. The inventory of thorium not in storage or as waste was maintained at Building 773-A. The primary work performed with thorium during this timeframe was as a surrogate for plutonium in testing of waste glass. Prior to 2004 workers were monitored by retrospective approach; e.g. radiation workers were chest counted. In 2004, with implementation of the ProRad radiation work permit system, Health Physics implemented a prospective approach to maintain doses as low as reasonably achievable. Protection and monitoring was selected by the area health physicist before a job with radioactive materials was started. NIOSH can capture these records if needed.

According to documentation and interviews, the Savannah River Site controlled workplace air concentrations in research laboratories in building 773-A to either 2% or 10% of the plutonium derived air concentration (DAC) (2×10^{-13} uCi/cc) from 1990 forward. NIOSH has reviewed

limited air sample data and confirmed that some laboratories known to use thorium in the post 1990 timeframe were controlled to the 10% DAC value. This review also indicated that the airborne concentration was considerably less than 10% of a DAC and typically on the order of <2% DAC. NIOSH has also reviewed radiological survey data in some laboratories known to work with thorium and found non-detectable levels of contamination indicating well controlled laboratories. Further, NIOSH has access to documentation that demonstrates radiation work permits (RWPs) were used to control and limit access to radiological materials. In addition, the RWPs prescribe monitoring of radiological materials such as thorium. These RWPs include sign-in sheets that limit and identify radiation workers exposed to radiological materials. These three programs (air monitoring, radiological surveys, and radiation work permits) provide solid evidence of a robust radiological control program in compliance with federal regulations (10CFR835). As a result, NIOSH plans to assign intakes to radiation workers involved with thorium work in Building 773-A from 1990 forward using the air concentration 2×10^{-13} uCi/cc. NIOSH intends to issue a report providing additional rationale for use of the derived air concentration.

Finding 28: *Due to conflicts between statements in the NIOSH ER and in the SRS Internal Dosimetry 2001 technical basis document (TBD), it is not possible for SC&A to definitively establish the date when the MDAs for chest counting described in SRS 2001 became operational. This problem would apply specifically to the 1990–1994 period.*

Response: The MDA given in the 1990 internal dosimetry basis document (SRDB Ref ID 11266) for Pb-212 (239 keV) is 0.13 nCi which is slightly less than the MDA of 0.15 nCi given in the 2001 version (SRDB Ref ID 722). The use of higher MDA given in 2001 is claimant favorable.

According to documentation and interviews, the Savannah River Site controlled workplace air concentrations in research laboratories in building 773-A to either 2% or 10% of the plutonium derived air concentration (DAC) (2×10^{-13} uCi/cc) from 1990 forward. NIOSH has reviewed limited air sample data and confirmed that some laboratories known to use thorium in the post 1990 timeframe were controlled to the 10% DAC value. This review also indicated that the airborne concentration was considerably less than 10% of a DAC and typically on the order of <2% DAC. NIOSH has also reviewed radiological survey data in some laboratories known to work with thorium and found non-detectable levels of contamination indicating well controlled laboratories. Further, NIOSH has access to documentation that demonstrates radiation work permits (RWPs) were used to control and limit access to radiological materials. In addition, the RWPs prescribe monitoring of radiological materials such as thorium. These RWPs include sign-in sheets that limit and identify radiation workers exposed to radiological materials. These three programs (air monitoring, radiological surveys, and radiation work permits) provide solid evidence of a robust radiological control program in compliance with federal regulations (10CFR835). As a result, NIOSH plans to assign intakes to radiation workers involved with

thorium work in Building 773-A from 1990 forward using the air concentration 2 x 10^{-13} uCi/cc. NIOSH intends to issue a report providing additional rationale for use of the derived air concentration.

Finding 29: *NIOSH has not compiled in-vivo counting data for the 1990–2007 period (including detection limits) that would be relevant to thorium intakes. Therefore, it is not possible for SC&A to evaluate whether thorium exposure potential was low or whether at least some fraction of workers, possibly small, had significant thorium exposure potential. It is also not possible to evaluate whether the quantity and quality of data are adequate for thorium dose estimation in the 1990–2007 period.*

Response: The inventory of thorium not in storage or as waste was maintained at Building 773-A. The primary work performed with thorium during this timeframe was as a surrogate for plutonium in testing of waste glass. A review of the first 10 records in NOCTS where the only job title was lab technician, where the claimant worked until 1993, and worked either in 773-A or 772-F showed that all 10 received FASTSCAN and chest counts though not all received chest counts after their final FASTSCAN count.

According to documentation and interviews, the Savannah River Site controlled workplace air concentrations in research laboratories in building 773-A to either 2% or 10% of the plutonium derived air concentration (DAC) (2 x 10^{-13} uCi/cc) from 1990 forward. NIOSH has reviewed limited air sample data and confirmed that some laboratories known to use thorium in the post 1990 timeframe were controlled to the 10% DAC value. This review also indicated that the airborne concentration was considerably less than 10% of a DAC and typically on the order of <2% DAC. NIOSH has also reviewed radiological survey data in some laboratories known to work with thorium and found non-detectable levels of contamination indicating well controlled laboratories. Further, NIOSH has access to documentation that demonstrates radiation work permits (RWPs) were used to control and limit access to radiological materials. In addition the RWPs prescribe monitoring of radiological materials such as thorium. These RWPs include sign-in sheets that limit and identify radiation workers exposed to radiological materials. These three programs (air monitoring, radiological surveys, and radiation work permits) provide solid evidence of a robust radiological control program in compliance with federal regulations (10CFR835). As a result, NIOSH plans to assign intakes to radiation workers involved with thorium work in Building 773-A from 1990 forward using the air concentration 2 x 10^{-13} uCi/cc. NIOSH intends to issue a report providing additional rationale for use of the derived air concentration.

Finding 30: *The FASTSCAN specifications indicate that the detection limit for thorium would be so high as to render it practically undetectable in SRS workplace situations.*

Response:

According to documentation and interviews, the Savannah River Site controlled workplace air concentrations in research laboratories in building 773-A to either 2% or 10% of the plutonium derived air concentration (DAC) (2×10^{-13} uCi/cc) from 1990 forward. NIOSH has reviewed limited air sample data and confirmed that some laboratories known to use thorium in the post 1990 timeframe were controlled to the 10% DAC value. This review also indicated that the airborne concentration was considerably less than 10% of a DAC and typically on the order of <2% DAC. NIOSH has also reviewed radiological survey data in some laboratories known to work with thorium and found non-detectable levels of contamination indicating well controlled laboratories. Further, NIOSH has access to documentation that demonstrates radiation work permits (RWPs) were used to control and limit access to radiological materials. In addition the RWPs prescribe monitoring of radiological materials such as thorium. These RWPs include sign-in sheets that limit and identify radiation workers exposed to radiological materials. These three programs (air monitoring, radiological surveys, and radiation work permits) provide solid evidence of a robust radiological control program in compliance with federal regulations (10CFR835). As a result, NIOSH plans to assign intakes to radiation workers involved with thorium work in Building 773-A from 1990 forward using the air concentration 2×10^{-13} uCi/cc. NIOSH intends to issue a report providing additional rationale for use of the derived air concentration.

Finding 31: *NIOSH has not provided information on how it will distinguish between Pb-212 results due to thoron from those resulting for thorium-232 intakes.*

Response: As previously discussed, NIOSH intends to use 10% of the derived air concentration rather than *in vivo* data to bound potential intakes of thorium.

Finding 32: *In the absence of a compilation of whole-body count (WBC) and chest count data, it is difficult to see how NIOSH will assign thorium doses to workers or construct a coworker model for the 1990–2007 period. There were thorium-related activities at SRS during this period.*

Response: NIOSH intends to use 10% of the derived air concentration rather than *in vivo* data to bound potential intakes of thorium.