2.6.2 Conflict of Interest Plan

We have chosen to modify SC&A's current OCI plan to reflect the provisions of this proposed work. Exhibit 2-2 presents this draft plan. In addition, Exhibit 2-3 presents the Conflict of Interest Certification that SC&A required each potential team member to sign prior to developing this proposal. Actual signed copies of this certification for each team member proposed are included in Appendix B.

Exhibit 2-2. SC&A Organizational Conflict of Interest Plan

PROPOSED ORGANIZATIONAL CONFLICT OF INTEREST PLAN FOR
CONTRACT RESULTING FROM CDC SOLICITATION NUMBER 2003-N-00768

Exhibit 2-2. SC&A Organizational Conflict of Interest Plan (continued)

[1] This conflict of interest plan will flow down to team members in their subcontracts.

Exhibit 2-2. SC&A Organizational Conflict of Interest Plan (continued)

Exhibit 2-2. SC&A Organizational Conflict of Interest Plan (continued)

Exhibit 2-2. SC&A Organizational Conflict of Interest Plan (continued)

Exhibit 2-3. Conflict of Interest Certification

TEAM MEMBER AND INDIVIDUAL CONFLICT OF INTEREST CERTIFICATION
CONTRACT RESULTING FROM CDC SOLICITATION NUMBER 2003-N-00768

Exhibit 2-3. Conflict of Interest Certification (continued)

Additional Certification for Teaming Partners and Key Personnel

I understand that my participation on this contract means that I will not be permitted to bid or perform any work for NIOSH, ORAU, or any of ORAU's primary teaming partners while performing work under this contract.

_____
Individual Name or Company Name

_____
Signature

_____
Date

2.7 Confidentiality and Security Provisions

SC&A fully understands the importance of protecting personal, proprietary, and other sensitive information to which we may have access under this contract. We have reviewed the provisions contained in HHSAR 352.224-70, Confidentiality of Information; FAR 52.224-1, Privacy Act Notification; 52.224-2, Privacy Act; and 52.239-1, Privacy or Security Safeguards, and are prepared to comply fully with all the requirements contained in these clauses.

Privacy Act

We will ensure that all individuals working on this contract with access to data protected by the Privacy Act are aware of the restriction on disclosure of records maintained on individuals and the conditions that must be met in order for disclosure to be permissible under the Privacy Act, Section 552a(b)(1)–(12). In addition, upon contract award, SC&A will establish procedures and policies with respect to (1) accounting for certain disclosures, (2) access to records, (3) relevant agency requirements, and (4) relevant agency rules.

Confidentiality of Information

In addition to the requirements of the Privacy Act, we understand that we will be subject to compliance with the provisions of HHSAR 352.224-70. We will obtain written consent from any individual, institution, or organization prior to disclosing confidential/proprietary information or data about that individual, institution, or organization. We will also provide the Contracting Officer with written advance notice of at least 45 days in the event that we intend to release findings of studies or research which have the possibility of adverse effects on the Agency. Finally, if we are unsure of the proper handling of material or information under this contract, or if the material in question is subject to the Privacy Act or is confidential information under HHSAR 352.224-70, we will obtain a written determination from the Contracting Officer prior to releasing, disclosing, disseminating, or publishing such information or material.

Security Safeguards

In the event that we develop or implement safeguards under this contract, we will not publish or disclose these safeguards without the prior written consent of the Contracting Officer. We agree to cooperate with the Government should it be necessary to carry out a program of inspection to safeguard against threats and hazards to the security, integrity, and confidentiality of Government data, and in this instance will provide the Government access to our facilities, installations, technical capabilities, operations, documentation, records, and databases. We understand that under this contract, should it become evident to either the Government or SC&A that existing safeguards have ceased to function, it will be the obligation of the discovering party to bring the situation to the attention of the other party.

All of our obligations under this section will flow down to our subcontractors at any tier.

3.0 TECHNICAL APPROACH[1]

This section describes our technical approach to performing basic and advanced case reviews, blind dose reconstructions, and Special Exposure Cohort (SEC) petition reviews. In addition, our approaches to performing reviews of worker-profile and site-profile databases, independent of the review of specific cases, and ad hoc reports are also described. Imbedded in the discussions are anticipated major problem areas, together with recommended approaches for their resolution. The section concludes with "Special Topics," which highlights those issues and technical strategies that we believe are worth noting, especially with regard to internal dosimetry.

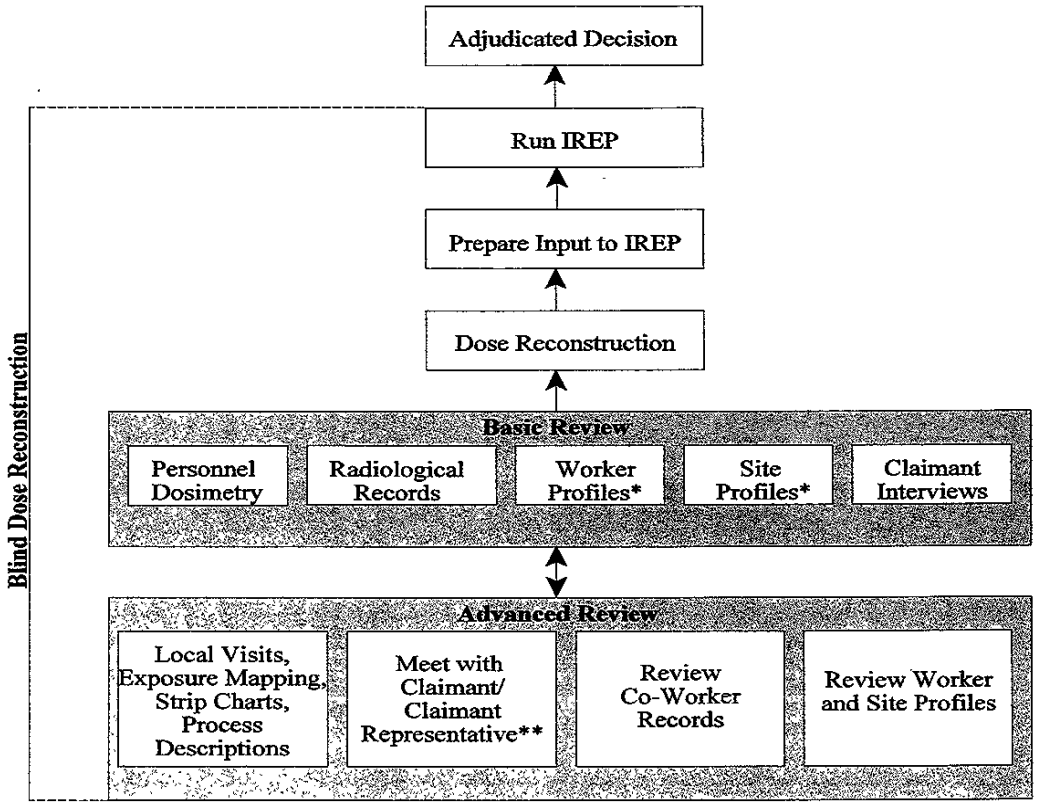
3.1 Concept of Operations

SC&A is proposing a highly structured, transparent, and well-documented approach to reviewing dose reconstructions and SEC petitions. Exhibit 3-1 presents our understanding of the interrelationships between the various tasks that comprise the review of dose reconstructions. Our technical approach to the project assumes that, whether the Task Order Request Package (TORP) requires a basic or advanced review, or a blind dose reconstruction, the administrative record and other pertinent technical material, in hard copy and/or electronic form, will accompany the TORP. These records, and any other information provided by NIOSH or uncovered as a result of our investigations, will be loaded into our relational database, which will be designed to be compatible and consistent with the relational database being employed by NIOSH.

In brief, for *Basic Reviews*, the focus of attention will be on the relevant portions of the administrative record and ensuring the completeness and internal consistency of the dose reconstruction, interview record, and, to the extent applicable to the basic review, NIOSH worker and site profiles. Primary attention will be given to the appropriateness of any assumptions that were used in the determination of dose as well as the completeness and internal consistency of the NIOSH dose reconstruction with Office of Compensation Analysis and Support (OCAS) guidelines in support of the dose reconstruction and the adjudicated decision.

Advanced Reviews will evaluate the entire administrative record and review pertinent worker and site profiles, seek out primary records (original log books, work permits, strip chart recorders, etc.), co-worker records, and supplemental information obtained from the claimant and co-workers (if authorized by the Board) as required to verify the dose reconstruction in those areas that could have a significant impact on the dose estimates and adjudicated decision. In order to perform advanced reviews in a manageable time period, advanced reviews will be limited to those exposure settings and occurrences that have the potential to significantly influence the ability to reconstruct doses and the resulting adjudicated decision. Nevertheless, during the

[1] This section, which describes our technical approach to the project, and Volumes 2 and 3 of the proposal which describe our technical approach to the two example tasks, cover many of the same points. We tried to avoid repetition. As such, we request that the committee reviewing our technical approach to this project consider Section 3.0 of Volume 1 of the proposal, as well as Volumes 2 and 3 in their entirety. Taken together, this information will offer the review panel a solid understanding of how we would approach tasks issued under this contract.



* Worker-profile and site-profile reviews will be part of the basic review only if they were used in the preparation of the original dose reconstruction prepared by NIOSH; otherwise they will be limited to advanced reviews or stand-alone tasks authorized under a Task Order.
**We recognize that direct conversations with claimants may not be authorized.

Exhibit 3-1. Interrelationships of Activities

course of advanced reviews, all findings will be documented, regardless of their importance to a particular dose reconstruction and adjudicated decision. We believe such findings may have relevance to the review of other claims and to the overall dose reconstruction process. *Blind Reviews* will be similar to advanced reviews, with the exception that the review team will not have access to the dose reconstruction, IREP input, and resulting adjudicated decision. Instead, blind reviews will include the performance of our own dose reconstruction and IREP calculations. The outcome of the blind review will then be compared to the dose reconstruction and IREP input/output resulting from NIOSH's investigations.

3.2 Preparation of Technical and Cost Proposals in Response to Task Order Request Packages

Upon delivery to SC&A, all TORPs will be logged in, date stamped, assigned a Task Order number, and placed into the dedicated project file which will be maintained under lock and key pursuant to SC&A's records management procedures (see Section 2.1). As a means of tracking

performance of each case or task comprising the TORP, the TORP will be subdivided into individual cases and/or tasks, and, as required by each case, may be further subdivided into lower-tier tasks, such as external and internal dose-reconstruction review, worker profile review, interview record review, and site profile review. Filing and tracking the cost and performance of each TORP will be performed under the following work breakdown structure:

Tier 1: Task Order Number
- Tier 2: Case Number
  - Tier 3: Dose Reconstruction
  - Tier 3: Worker Profile
  - Tier 3: Interviews
  - Tier 3: Site Profile
- Tier 2: SEC Petition Review
- Tier 2: Worker Profile Review
- Tier 2: Site Profile Review
- Tier 2: Ad Hoc Investigations

Using a relational database, we will be able to sort according to site (e.g., Hanford, Savannah River, etc.), category of site (e.g., FUSRAP site, uranium processing facilities, etc.) category of exposure (e.g., external gamma, plutonium inhalation, etc.), or any other parameter that may serve the Advisory Board's purposes.

While the TORP filing system is being set up, each key member of the project team (see Section 2.1) will receive copies of the TORP for initial inspection with respect to scope, schedule, resource requirements, and conflict of interest (COI) issues. A meeting will be held among the key members of the project team to discuss the TORP and any supporting records and documentation provided with it. The meeting will be designed to accomplish the following objectives:

- Identify questions and concerns to be discussed with the Project Officer and/or Advisory Board representatives. If acceptable to the Project Officer and the Board, it may also be useful to begin discussions at this time with the NIOSH contractors who prepared the dose reconstructions.

- Identify the Case Managers and/or Task Managers and assemble the teams for performing the work required by each case or task contained in the TORP.

- Prepare a schedule for completion and delivery of the technical and cost proposal. Under the direction of the Project Manager, a comprehensive technical and cost proposal will be prepared that meets the requirements of Section H.20 of the solicitation and that will be delivered to the Project Officer within 14 calendar days of receiving the TORP. The first step in the preparation of the technical and cost proposals for both basic and advanced reviews is to inspect the input and output of the IREP computer run for each case. Case Managers will then be selected based on either their familiarity with the site or category of the site and/or special technical issues associated with the exposures (e.g., the case is limited to

reviewing the dose reconstruction of a person who experienced internal exposures to inhaled plutonium and the associated bioassay data). The administrative records provided with the cases will be used to define the qualifications of the Case Managers and technical specialists who will be assigned to each case.

For basic reviews, it may only be necessary to assign a single individual to perform the review. However, for advanced reviews and blind dose reconstructions, a minimum of three individuals will be assigned to each case. As required by the TORP, these individuals will have the following assigned functions: Dose Reconstruction Reviewer (perhaps separated into internal and external doses), Worker Profile Reviewer, Interview Records Reviewer, and Site Profile Reviewer. One of these individuals will also be the designated Case Manager. We recognize that some of the basic reviews will not require access to the NIOSH worker profile or site profile database; however, we will be prepared to review these sources of information as required to complete the basic or advanced reviews, or blind dose reconstructions. The individuals assigned to each case can draw upon any of the other specialists on the project team. The teams will be assembled using the following criteria:

- Familiarity with the site
- Familiarity with the health physics issues at the site
- Ongoing case commitments
- Consistency of team makeup

In general, for basic reviews, the Case Manager will likely be a health physicist with specialized expertise in the primary types of exposure of concern (e.g., external exposure versus inhalation of plutonium) and the associated dosimetric records. For advanced reviews, the Case Manager could be an appropriately qualified health physicist or an individual with in-depth experience with the site or types of operations responsible for the exposures.

3.3 Procedures for Performing Basic and Advanced Reviews

Following approval of the technical and cost proposal, the Government will issue a Task Order and work will commence. For basic and advanced reviews, the individuals comprising each of the teams assigned to each case will review the IREP input and results to determine technical areas of emphasis (e.g., acute versus chronic exposures, external gamma or neutron exposures, internal exposures and radionuclides of concern, etc.) that are the primary drivers for the outcome of the IREP calculations. Based on this initial review, additional specialty resources (see Section 2-1, the charts and biosketches in Section 4, and the resumes in Appendix A) will be drawn upon as needed to perform the review. The review of each case will then commence under the direction of its assigned Case Manager.

Each case will be reviewed by the team assigned to the case, and, depending on the complexity of the case, review responsibilities may be divided into internal and external dose reconstruction reviews (which will include a review of the claimant interview record). In addition, for some basic reviews and all advanced reviews, the review process will also include worker and site profile reviews, as required by the technical proposal and Task Order. If several cases are from the same site, there may be efficiencies we can incorporate into the process by assigning a single

individual to perform the worker and site profile reviews for those cases. However, for complex sites, where operations were highly diverse in space and time, such as at several major Federal facilities, the supporting worker profile and site profile reviews may be highly unique to the operations associated with the particular worker, or category of worker, and the specific campaign at the site at a given point in time.

As described in greater detail in the example tasks, as our team becomes more familiar with worker and site profiles for specific sites and categories of operations, Case Managers and team members will be assigned to each new case in a manner that takes advantage of the experience and knowledge gained by previous reviews. As such, we expect that we will become increasingly efficient in performing both basic and advanced reviews as we acquire experience. However, it is important to note that we will be beginning this process with individuals who already have a great deal of experience and knowledge of the operations and exposure histories of many of the DOE sites (e.g., see the biosketches of
).

The following sections describe the checklist and procedures for performing external and internal dosimetry reviews, worker profile reviews, claimant interview reviews, and site profile reviews. The checklists are extensive, and, in most cases, only those portions of the checklists that apply to a particular case will need to be completed in detail.

During the review process, there will be a great deal of interaction among the review team members in order to evaluate and ensure internal consistency and compatibility of the dosimetric information with the worker profile information, the claimant interview information, and with the site (or event[2]) profile. We suggest that, throughout this process, SC&A have an opportunity to obtain clarifications and discuss our preliminary findings with Advisory Board representatives, and, if acceptable to the Advisory Board, with the original authors of the dose reconstructions. In addition, as work proceeds, should we uncover substantial errors or deficiencies in a dose reconstruction, we will immediately contact the Advisory Board representatives, and not wait until our reports are completed and delivered. We hope to establish a very close and cooperative relationship with the Board members and seek their counsel throughout the review process.

Accompanying each item in the checklist will be a narrative explaining our findings. The level of detail of the review will differ between the basic and advanced reviews. Blind dose reconstructions will be performed in a similar manner as the advanced reviews, except the review team will not have access to the IREP input and output prepared by NIOSH. In this way, our team will perform an independent dose reconstruction, the results of which can be compared to the results provided in the administrative record.

[2] For some cases, a major contributor to exposure may have been a transient or accidental release, referred to here as an "event," which will require a more focused historical reconstruction of the exposure setting than what would normally be contained in a site profile, where exposures occurred as a result of routine operations.

3.3.1 External and Internal Dosimetry Review Procedure and Checklists

The basic and advanced individual dose reconstruction review processes will each utilize a checklist for conducting the technical reviews. The checklists are provided in Appendix C. The checklists are designed to satisfy the basic level and additional advanced level review elements specified by the NIOSH Advisory Board Dose Reconstruction Working Group. The checklists allow the basic/advanced review process to be conducted in a systematic, consistent, efficient, and transparent manner. They will also serve as a means of tracking and formally documenting the individual steps of the audit process. When the audit is completed, the information collected in the checklist will be entered into a database in a format that is compatible with Microsoft SQL 2000. All records/documents collected and used in the audit process that were not included in the case file will be duplicated and provided to NIOSH.

The basic individual dose reconstruction checklist is structured to evaluate the following five areas of review: (1) data collection process, (2) interview/claimant documentation, (3) external dose reconstruction process, (4) internal dose reconstruction process, and (5) applicable portions of NIOSH procedures and methodologies associated with the reconstruction of dose for each individual case . When an advanced dose reconstruction audit is requested, a second checklist will be completed, which incorporates elements that will provide for a more extensive review of the data gathering, work-history interview, and external/internal dose reconstruction processes. These checklists are designed to take into account all requirements established in the *U.S. Code of Federal Regulations* (CFR) Title 42, Part 82, and follow guidelines provided in the External and Internal Dose Reconstruction Implementation Guidelines (OCAS-IG-001 and OCAS-IG-002, respectively), as well as other relevant technical documents. However, it is recognized that, due to the variety of conditions associated with each individual's exposure scenario, these checklists may not be all inclusive. The intent of the checklists is to provide the auditor with a roadmap to evaluate the dose reconstruction process in a stepwise, thorough, and reasonable manner.

3.3.2 Claimant Interview Review Procedure and Checklist

The claimants, their family members, and co-workers play a key role in the dose reconstruction process, especially for the advanced reviews. In general, basic reviews will be limited to a review of the completed questionnaire and the degree to which that information was appropriately incorporated into the dose reconstruction. Advanced reviews will go beyond a simple checking of the questionnaires. Work history interviews will be assessed for their effectiveness and, in the cases involving survivors, will evaluate whether a reasonable effort was made to follow up on information provided by the claimant (i.e., contacting co-workers and tracking down historical records). Advanced reviews may also include approved follow-up interviews.

For each claim, NIOSH will conduct a voluntary interview with the claimants or their survivors which will allow them to collect detailed information concerning the claimant's employment history, work environment, and radiation monitoring history. All of this information, which will be contained in the structured interview forms used by NIOSH, should be considered by NIOSH when performing the dose reconstruction, and should be consistent with the information gathered by NIOSH from the DOE/Atomic Weapons Employer (AWE) personnel and site-monitoring

records. The following describes our approach to basic and advanced claimant-interview reviews, including the checklist in Appendix C that includes elements addressing the NIOSH questionnaire. This will be used to evaluate the completeness of the NIOSH questionnaire and to compare the information provided by the claimant or survivor during the interview with the other information in the administrative record.

The audit of worker and family interviews will include (1) specific elements relating to the use of each worker interview that is audited in the process of dose reconstruction, and (2) general elements relating to the methodological aspects of the relationship of interviews to dose reconstruction.

Specific Elements

The audit of every worker interview will be closely coordinated in each case with the various elements of the overall audit of the dose reconstruction for that worker. Specifically, the audit will involve:

- Determining whether the elements of the worker interview regarding frequency of film badge changes, the components and frequency of various types of monitoring of internal burdens of radionuclides, and the monitoring of the general air in the work environment have been checked against the facility profiles for the period in question and against the dose records of the worker.

- Checking how the discrepancies between the worker's account, the dose records, and facility profiles have been dealt with in regard to the estimation of the uncertainties in the dose estimates from particular radionuclides.

Depending on the results of the dose reconstruction, highly specific "forensic health physics" follow-up inquiries may be required. For instance, a worker job description might include sitting astride uranium metal ingots to stamp serial numbers on them (as was the practice at Fernald). The film badge doses could seriously underestimate external exposure to the gonads, and hence the total effective dose equivalent (TEDE), and misrepresent the doses to specific organs of interest. As another example, the time at which urine samples are taken may influence the concentration of uranium in the urine. For instance, Monday morning urine samples taken after coffee would tend to reduce reported concentrations relative to actual averages. In addition, depending on the solubility of the compound, Monday morning urine or feces samples may also result in an underestimate of doses. Such practices could distort dose estimates, especially if samples were taken infrequently. Other important questions include: (1) Did the worker collect 24-hour excreta samples or just an aliquot? and (2) Was the worker under medication (diuretics, for example, may affect the excreted activity and other drugs may affect the analytical processing of the samples)? Worker interviews will be used as a way of checking on the completeness of specific aspects of workers' dose records and to help focus follow-up inquiries to find records that may be missing or misplaced and which could be critical to the dose reconstruction and the resulting PC calculations. The audit will include an evaluation of the adequacy of such efforts deriving from worker interviews.

General Elements

When a sufficient number of worker interviews and records have been audited for specific facilities or processes (such as uranium chemical processing or machining, plutonium processing or machining, etc.), a check will be made about whether and how the worker interview data have been used in conjunction with facility profiles. Consistent worker testimony about the frequency of badge use or internal monitoring, for instance, could lead to discovery of gaps in facility documentation. Hence, worker interview data can be pooled to provide insight into the quality of and uncertainties in dose estimates for specific facilities or processes. The audit will examine whether the worker interview data have been used to the extent possible to improve the quality of dose estimates for groups of people who worked in specific processes or places.

When the audits of worker interviews and dose records from a sufficient number of different facilities and processes are complete, worker interviews can then be used to determine the adequacy of dose records across the nuclear weapons complex as a whole for specific time periods and processes.

This pooling of worker interview and dose data will allow an analysis of possible patterns in the discrepancies between worker accounts and dose data at specific facilities and over the entire complex. The dose reconstruction methodology will be audited to determine whether the worker interview and records have adequately taken these patterns into account in order to improve dose estimates, and possibly to develop correction factors to dose estimates, in case they are warranted.

Examples of Importance of the Interview Process

Example 1. Thorium-232 Processing

Thorium was processed at a number of facilities, such as the Simonds Saw & Steel Co., Lockport, NY (a FUSRAP site) and at the Fernald plant. The following quote from the study performed for *USA Today* about this (and two other sites) is illustrative of the importance of the interviews. This quote is about Simonds Saw & Steel:

> *Thorium processing operations may have taken as little as one week and possibly much longer.[3] Based on available data, it is not possible for us to estimate the total number of full time equivalent days for which the thorium milling operation was conducted. We have therefore calculated thorium doses corresponding to*

[3] The study was unable to make a reasonable estimate of the number of days for which thorium was processed. Hence, there is a corresponding uncertainty concerning worker exposures to thorium. The lowest estimate of working time was one week of full time work for thorium processing based on a comparison with uranium processing rates. The thorium throughput per hour would be about 40 percent of the uranium throughput per hour due to the difference in mill sizes (10 inches versus 16 inches, yielding a cross-sectional area ratio of about 40 percent). A June 8, 1953, document indicates that thorium processing rates may have been somewhere between roughly 1,000 pounds and 4,000 pounds per day, assuming that all work indicated in a month's period was done in a single full working day. On this basis, the total thorium processing time can be estimated to be between 10 and 40 working days—that is, 2 to 8 weeks. [Survey of Accounting Control over Source and Fissionable Material, Simonds Saw and Steel Company, Lockport, New York, with cover letter dated June 8, 1954.]

one week of full time work. Bone surface doses over a one-week exposure period would range from about 400 rem to almost 2,500 rem, depending on working conditions and thorium solubility. We do not have a basis on which to select a mix of solubilities based on the available data. If the work was carried out for several weeks, then the dose estimates would be correspondingly higher.

Overall, it appears that exposures to specific workers who worked on thorium may have been severe. We have not been able to assess cumulative thorium exposures in a manner similar to uranium since we lack even minimally adequate air concentration data over the requisite period of time. Our estimate of thorium exposures corresponding to one week's work indicates that, for some workers, thorium exposures may have been comparable to and perhaps greater than uranium exposures. Finally, if some workers worked on both uranium and thorium, those exposures would be additive.

The dose estimates above were made from workplace air concentration data. Worker interviews regarding the amount of time for which thorium was processed could be critical in cases like this to make an estimate of the dose, since the documentation for this was not contained in the facility profile that was available to the dose reconstruction personnel.

Example 2. Recycled Uranium

Recycled uranium was processed at a number of facilities (both DOE-owned and FUSRAP). Trace transuranic radionuclides (Pu-239/240, Np-237) can make a significant contribution to the worker dose. However, the levels of transuranics in recycled uranium varied by orders of magnitude, ranging from levels which would play no significant role in the dose to important contributors to dose. A crucial parameter in determining this would be the stage of processing at which the worker handled the uranium. For instance, plutonium concentrations at Paducah were higher at the fluorination tower relative to several other places and steps of processing. Specific job descriptions are therefore very crucial, since plant air monitoring data and biological measurement data usually do not contain radionuclide-specific information. Similarly, information on whether respirators were used is also important.

In light of the above, estimating the contribution of transuranics in recycled uranium processing is typically very difficult and involves carefully combining worker interviews, worker monitoring records, plant air monitoring data, and production data in facility profiles. Auditing worker interviews to determine whether they had adequately covered the worker's history with recycled uranium could be a critical component of individual dose audits at many DOE and FUSRAP sites. Coordinating facility profile and worker interview data across facilities may also be insightful. For example, recycled uranium at Fernald came from Paducah.

Audit Interview Forms

Besides the specifics of the audit, discussed above, we will also review the interview forms for adequacy as applicable to a particular case. Some gaps that may hinder complete elicitation of potentially important information from workers could include the following:

- The NIOSH questionnaire does not address food in the work place. Workers often ate in contaminated places and may have stored their food in contaminated places.

- There is no question about handling of badges. This could affect badge readings.

- The questions about badges imply that a worker would have worn only one badge (except to the extent that one question asks what part of the body the badge was worn). At Fernald, some workers had wrist badges, and some workers may also have worn ring badges.

- The reference to monitoring of "breath" is too vague to elicit data on breathing zone air contamination measurements. Many workers wore these portable air samplers. The interview form asks the question about monitoring "breath" in the context of biological monitoring, such as occurs after an inhalation of radionuclides. This may cause a worker to miss mentioning breathing zone measurements, which are not biological measurements, as such. Breathing zone data could be crucial in determining internal dose in some cases, especially where biological monitoring documentation is missing, as may be the case for many workers at FUSRAP facilities.

- The questions may not reveal the specific ways in which the particular worker may have come into contact with radioactive material. As is clear from the example of workers who stamped uranium ingots at Fernald (formally called the Feed Materials Production Center during the period of production, 1951–1989) noted above, it is necessary to go into the physical details of how a worker processed radioactive materials or handled them in considerable depth.

- The only question about neutrons relates to neutron-generating facilities. This omits neutrons from spontaneous fission of various isotopes, notably Pu-240, as, for instance, in Pantex igloos.

Audit Form Review Checklist

In order to facilitate and standardize the documentation of our reviews, the forms presented in Appendix C will be used, in part, to explicitly evaluate the thoroughness of the completed NIOSH questionnaires.

3.4 Procedures for Worker Profile Reviews

SC&A will review selected worker profiles from NIOSH's database to ascertain the quality and completeness of that database to support individual dose reconstruction. These reviews can be performed as part of the review of a given case, or as a stand-alone Task Order requested by the Advisory Board and authorized by the Project Officer. To accomplish these twin objectives, SC&A will address the following questions: (1) Are the data of sufficient quality and reliability to be used as a means to estimate dose when individual dose records are inadequate or not complete? (2) Have all relevant dose records with personal identifiers, such as plant records, monitoring data, memorandums, electronic databases, and accident and occurrence reports, been included? (3) Has there been sufficient characterization of historic radiation protection programs in place, including personnel monitoring requirements, protective equipment practices, dosimetric techniques and equipment in use, and procedural enforcement history?

3.4.1 Quality and Reliability of the Database

The quality and reliability of the database will be a function of the number of data points available for a particular job category, the facility process location or time period, and the consistency of the data entered in comparison with the original source information. As the worker profiles are populated with data from DOE sites, some searchable fields will contain more data than others, as will some facilities, and locations and time periods within facilities. "Missing data" will be apparent for certain operations and time periods due to any one of the following reasons:

- Lack of personnel monitoring data (dosimeter not assigned or not processed)
- Inadequate monitoring techniques
- Errors in transcribing dosimetry readings to official reports, historic dosimetry practices that ignored certain exposure sources (e.g., radon, low-energy photon, neutron), etc.

One important issue is the quality and reliability of electronic dose-record databases submitted by DOE for a site or facility. Unless these submitted databases have been verified from a quality assurance standpoint against the original source records at the site, they cannot be considered fully reliable. In its September 2000 Exposure Assessment report for the Paducah Gaseous Diffusion Plant, a review team consisting of DOE, University of Utah, and the Paper, Allied Industrial, Chemical and Energy Workers (PACE) International Union found a number of instances where the data on the "official" Paducah electronic historic worker dose database did not encompass all dosimetry records over the history of the plant.

At Paducah, the aforementioned exposure assessment found that the following limitations existed for personal external radiation exposure measurements, uranium urinalyses, and whole-body counting in the electronic database.

- While early health physics reports indicate that limited in-vitro bioassay monitoring for transuranics was conducted, there are no urinalysis data in the electronic databases prior to 1989.

- The historical urinalysis databases did not indicate the type of sampling (routine, special, etc.) or the solubility class of material being monitored.

- The databases have not been verified against any of the original records.

- The databases have not had any quality assurance/quality control evaluations.

- The databases are not complete; for example, it was determined that at least some elevated data from exposures as a result of incidents and accidents were not included in the electronic database. The database may contain data-entry errors.

- Some of the units used in the database are not clearly documented.

- Not all department numbers found in the health physics reports could be correlated with the department numbers recorded in the electronic databases.

The evaluation team in this case concluded that, "based on the above, the databases should not be used at this time to estimate individual worker doses."

As the NIOSH worker profiles will initially consist of many of these historic site electronic databases, SC&A intends to do sufficient "sampling" quality verification checks to assure that their reliability can support application to individual dose estimation. This will be accomplished by identifying the original source data and comparing them with the submitted electronic or hard copy data used in selected worker profiles. The degree and nature of potential "missing doses" will be determined as a means to ascertain the representativeness and usability of profile data. As dose reconstructions proceed over time and reconstructed individual doses are added to the database, the representativeness of the database will steadily improve, aided by these quality verification reviews.

3.4.2 Completeness of Records Incorporated

Each DOE site, if not facility, has a unique operational, radiological, and managerial history. While DOE and its predecessor agencies (Manhattan Engineering District, Atomic Energy Commission, Energy Research and Development Administration) issued directives governing radiation protection standards, dosimetry and record keeping in the early decades (1940s–1980s) were typically general and left to individual contractor interpretation and implementation. To gauge the completeness of records reflected in the NIOSH worker profile, SC&A will verify the "universe" of radiological data having identifiers for a particular facility or site, and compare that data with what is entered in the selected profile.

For this review, it will be essential to identify what monitoring was conducted for different types of radiation, for what worker categories and time periods, and in what form and condition the

source records exist. For many sites, source records, such as old dosimeter readouts, microfiche urinalysis results, and incident reports with estimated exposures can be located through deliberate inquiry and onsite searching. In other instances, databases have been compiled in the past as part of broader worker dose surveys, epidemiological studies, or summary radiation dose reporting. It needs to be ascertained that all such databases have accessible identifiers. Some summary reports, such as the Radiation Exposure Information Reporting System (REIRS), have originating identifiers that are maintained by the project manager.

To determine the completeness of records available to the NIOSH worker profile, it may be necessary to make inquiries of workers and records management personnel at some sites. The purpose of these inquiries is to identify the possible availability of records (with identifiers) based on recollections of programs, incidents, or procedures where monitoring may have taken place, and where corresponding records may have been maintained. In the early years, these are often at the facility or operations level and may not have been compiled in formal radiation dose records. SC&A will make inquiries to independently verify that the profile is complete from this standpoint.

3.4.3 Characterization of Historic Radiation Protection and Dosimetric Practices

Another issue is whether the appropriate caveats and limitations of the profile data are reflected. Each site radiation dosimetry program had a unique history and technical evolution. Some sites have conducted retrospective dose reconstructions to develop a reliable historic worker dose database and have reflected the limitations and qualifications associated with the dose values cited for individuals. Others have simply collected and reproduced available dose records without any effort to acknowledge or compensate for the inadequacies or incompleteness of the resulting database. Tritium and neutron doses were included and recorded for the first time at varying times at different sites. Urinalysis policy and recording thresholds vary widely as a function of radionuclide, operation, and site. Certain radiological source terms, such as trace contaminants in process streams, were not measured routinely, and what exposure records exist can be found in operational reports estimating doses to workers on a particular process line. SC&A will review the historic status of site radiation records for selected worker profiles and ascertain whether the dose information provided is consistent with them.

3.5 Reviewing Site Profiles

SC&A will review selected site profiles as determined first by NIOSH direction, and second by relevant aspects of site profiles associated with cases undergoing advanced dose reconstruction review (the latter will provide a two-for-one economy of work that will support both sampling objectives).

The NIOSH site profile database is designed to support the conduct of individual dose reconstructions by compiling data other than dosimetric information, such as that related to facility operations and processes over time, radiological source term characterization, chemical and physical forms of the radionuclides, historic workplace conditions and practices, and incidents and accidents involving potential exposures. SC&A will evaluate the quality and

completeness of this information to ascertain the adequacy of the information contained in the NIOSH site profiles.

SC&A will identify and evaluate the approach taken in compiling the site profiles through a comprehensive process of (1) independently identifying the selected site's operational history, (2) conducting an "exposure mapping" exercise to identify historic work processes and worker categories, (3) reviewing all relevant data sources, such as occurrence reports, inspection documentation, safety analyses, etc., and (4) interviewing worker representatives, worker advocacy groups, and other individuals having knowledge or expertise on site operational or radiological history.

3.5.1 Reviewing Site Operational History

For many DOE and AWE sites, reliable dosimetry records may be lacking, particularly for workers from the 1940s through 1960s. In these instances, historic operational information that includes the nature of operations, radiological source terms in use, process material concentrations, and location and time periods of worker activities may be the only data available for dose estimations. Such information can be extracted from historic records and documentation being collected by (or accessible from) DOE, including operational records, material inventories, safety and health inspections and assessments, occurrence reports, and routine memoranda and facility reports. This possible source of information will be surveyed at the DOE site or AWE records collection point to ascertain whether the site profiles adequately reflect at least the following information, where feasible:

- Operational processes over time, including improvements, upgrades, modifications and terminations *(important because worker exposures are often higher during major process changes).*
- Historic radiological inventory, source terms, and movement through facility ("mass balance") to include feed material, products, and byproduct and waste streams.
- Any unplanned events, including radiological over-exposures, contaminations, releases, spills, criticality incidents, and unusual occurrences.
- Changes in contractor management and attendant changes in safety policies, procedures, and practices *(important because new contractors import new radiation protection programs).*
- Applicable standard operating procedures, memoranda, directives or recorded practices governing onsite management of radioactive materials and processes.
- Actual historic operational practices established by first hand accounts (e.g., worker representatives, site "experts," etc.) *(important because actual facility practices often varied from official procedures).*

- Historic radiation protection programs in place, including personnel monitoring requirements, protective equipment practices, dosimetric techniques and equipment in use, and procedural enforcement history *(important to determine whether and to what degree the dosimetry program reflected actual potential exposures possible, given source terms involved).*

- Worker rosters with identifiers, work assignments and location, as well as summary of work histories sufficient to determine what categories of workers were assigned to what type and locations of radiological work.

It would be useful to have data on the number of monitored workers, number of workers with doses higher than the minimum detectable levels, average measurable recorded doses, minimum detection levels, and whether doses below the detection limit were recorded as zero. Even better would be to have data on the number of workers in specified dose ranges.

The foregoing information will be used in a comparative manner to ascertain whether the site profiles are complete in how they characterize, from a historic standpoint at a particular site, what radiological materials were present and in what concentrations and chemical forms; what worker groups may have been in proximity with sources of exposure and whether certain activities or unplanned events may have made such exposure likely; and what administrative procedures, operational practices, protective equipment use, and facility conditions may have influenced the likelihood of such exposure. The quality of the profile will be evaluated by what can be termed "exposure mapping."

3.5.2 Conducting "Exposure Mapping"

Exposure mapping will be used to evaluate the extent to which the profile provides information that can characterize the potential radiation exposure to which workers may have been exposed in specific work activities and locations or time periods at the site in question. Sources of information include published site reports, memoranda, area monitoring data, process descriptions, and general worker exposure summary information. Higher activity radiological sources in the facility's process streams will be linked to those worker categories and locations where potential exposure levels were highest.

An example of the types of published information that can provide historical site information that can be very helpful in preparing and reviewing site profiles is "Exposure Assessment Project at the Paducah Gaseous Diffusion Plant," prepared by PACE and the University of Utah on behalf of the DOE Office of Environment, Safety, and Health (September 2000). Table 7-3 from that report is one example of the outcome of an historical exposure mapping for the Paducah Gaseous Diffusion Plant. This type of information can be compiled for virtually any site, and can be extremely valuable in a blind dose reconstruction and in an advanced review of a NIOSH dose reconstruction.

3.5.3 Reviewing Relevant Data Sources

SC&A will determine whether the NIOSH dose reconstruction contractor appropriately identified, evaluated, and incorporated all relevant data sources by comparing the extent to which such information is present in the profile with what can be identified via an independent review of such sources of information. Data sources that will be scanned include the following:

- Department of Energy
  - Field Offices
  - Operating contractors
  - Institutional histories
  - Inspector General files
  - Headquarters and field oversight reports
  - Radiation exposure assessments
- Atomic Weapons Establishment
- Centers for Disease Control
- Nuclear Regulatory Commission
- Environmental Protection Agency
- General Accounting Office
- Defense Nuclear Facilities Safety Board
- Congressional Hearing Records
- State environmental and safety regulatory agencies
- National Academy of Science
- Administrative/court records
- *Department of Defense*
- Environmental Measurements Laboratory (formerly the Health and Safety Laboratory)
- Workers compensation records
- Worker and public advocacy groups
- Historic records in private hands

It is anticipated that a baseline of relevant information contained in these and other data sources will be established at the onset, facilitating subsequent comparisons with site profile information.

3.5.4 Interviewing Sources of Site Knowledge

SC&A, as necessary, will conduct one-on-one or group interviews with selected sources, including worker representatives, worker advocacy organizations, individuals with site "expertise" due to past employment or familiarity with operational history, and others who can verify the adequacy of site profile information that has been collected by the NIOSH contractor. Interviews will be conducted where convenient for these groups, including near the actual site in question. Lines of inquiry would include the following:

- How did actual radiation protection practice compare with documented policy and procedures?

- Were there instances of obvious "missed dose," e.g., not wearing or improperly wearing dosimeters, non-recording of dose, etc.?

- Were there any incidents involving potential radiation exposure, whether reported or unreported?
- Were there special work activities or facility modifications which constituted process changes that increased radiation exposure potential?
- Were workers concerned about past exposure or radiation protection practices? How did management respond and what, if any, changes occurred in onsite practice?
- Did workers wear protective equipment, as required?
- Were radiological jobs planned for exposure minimization (e.g., ALARA)?
- What was the general housekeeping in the facility; was radiological contamination common during the history of the facility?
- Were there special feed materials introduced or contaminants of concern identified from which radiation exposures may have resulted?
- Were there certain work activities at the facility that were considered "hotter" jobs from the standpoint of potential radiation exposure?
- Were safety procedures followed literally and did management assure that they were enforced uniformly?
- In terms of conduct of operation, were workers permitted to smoke, eat, or drink in control areas? Was protective clothing and equipment worn in these areas; was egress monitoring conducted?
- Were negative or "zero" doses recorded on periodic dosimetric records despite known exposure to significant radiation sources?
- Were records and other documentation of radiation exposure discarded or retained by management?
- Were there cases of over-exposed film and how were they treated?

The information extracted from these interviews will be used to ascertain the completeness and representation of that in the NIOSH site profiles.

3.6 Blind Dose Reconstruction

A great deal of information, procedures, and guidelines are provided throughout this proposal that demonstrate how we will go about performing basic and advanced reviews, worker profile reviews, and site profile reviews. Given this as background, suffice it to say that our procedures

for performing blind reviews will be in accord with OCAS-IG-001 and OCAS-IG-002, with all the qualifiers for ensuring quality that are described in depth in the other sections of this proposal. Upon completion of each blind review, the work products will receive the same independent advanced review audits as performed for NIOSH dose reconstructions as a form of quality assurance documentation.

3.6.1 Internal Dosimetry Procedures and Software.

For internal exposures, the document OCAS-IG-002 recommends for dose reconstruction purposes the use of the International Commission on Radiological Protection's (ICRP) most recent biokinetic and dosimetric models. Bioassay measurements, when available and reliable, should be used as a basis for relevant dose calculations. The interpretation of monitoring bioassay results, using ICRP models, requires the derivation and use of intake retention functions (describing body and organ contents) and excretion functions (describing activity in excreta), as a function of time following intake. Once the intake is estimated, the committed effective dose and the annual/committed organ dose are calculated by multiplying the intake by the appropriate dose coefficient.

As the models describing the uptake, distribution, and retention of radionuclides taken into the body are complex, the interpretation of bioassay data requires the use of a computational code that is based on the recommendations of the ICRP. Publication 78 of the ICRP [*Individual Monitoring for Internal Exposure of Workers*, Annals of the ICRP 27 (3-4), Pergamon, 1997.] gives limited information on the interpretation of bioassay data for selected radionuclides, for selected times after an acute intake and some graphical information on chronic intakes. We will use NIOSH guidelines to perform blind reconstructions, and NIOSH-recommended software. If the Task Order does not specify particular software, we will use a computational code that uses the ICRP's most recent biokinetic and dosimetric models. There are few computer codes that utilize the new ICRP models. Most of them are not commercially available, were developed by ICRP members, and are used in their home institutions. The ICRP does not recommend the use of any particular software. The one we will use, if agreed by the Task Order, was developed by ICRP members and was officially adopted by the International Atomic Energy Agency (IAEA), for use in Latin America in its program for Harmonization of Internal Dosimetry Programs, involving 10 countries in Latin America. This software has been benchmarked against ICRP 78 for all radionuclides and all times contained in the publication and reproduces ICRP 78 graphs for chronic intakes. It has all features necessary to reconstruct occupational radiation dose from internally deposited radionuclides as specified in OCAS-IG-002.

This software accepts input information on various types of measurements, e.g., urine, feces, lung, thyroid, bone, whole body, etc. Urine activities may be given as 24-hour excretion rates or on a per liter excretion rate. If given on a per liter basis, unless otherwise specified, a nominal excretion rate of 1400 milliliters (ml(of urine per day will be used. Fecal excretion activities may also be given as 24-hour excretion or on a per gram or per gram of fecal ash basis. Unless otherwise specified, the nominal excretion rate of the ICRP reference man will be used. The software accepts inhalation of gases and particles, ingestion, and injection as routes of entry. It accepts inputs on information on the elements or compounds, such as number of radionuclides available for intake (item 4.2, OCAS-IG-02), physical-chemical characteristics of the compound

(AMAD or absorption parameters) and choice between default and specific values (items 4.3 and 4.4, OCAS-IG-02). Radioactive progeny that grow in after an intake of a parent radionuclide are treated as recommended by the ICRP. Generally, it is assumed that the biokinetic behavior of the decay products is the same as that of the parent nuclide. However, in the biokinetic models for tellurium, lead, radium, thorium and uranium, separate systemic biokinetics are applied to the parent and its decay products, as specified in ICRP 71. An input for the intake of progeny is available, in an optional basis, with chosen equilibrium factors (item 4.2.3, OCAS-IG-02). This feature is very important when decay products are used to assess intakes of the parent.

The software calculates excretion rates and accumulation of radioactive material per unit intake in all organs described in ICRP current models for single intakes, chronic intakes, and exposures during a certain period of time. Thus, it is possible for all those scenarios to produce annual doses, committed doses until date of diagnosis of cancer or throughout the individual's entire employment, for all organs and tissues described by ICRP models as specified in OCAS-IG-02, as well as 50-year committed doses. In addition to calculating organ doses for the most probable intake scenarios, results from all those scenarios may be easily and rapidly compared, as required in items 6.1 and 6.2 of OCAS-IG-02.

When detailed dose reconstruction is required, a special feature, workers' chronic intakes (x days a week, y hours per day, and w days of vacation—for example, 5 days per week, 8 hours per day exposure, 2 days weekend and 20 days vacation) may be used. The workers' pattern of exposure takes into account the smaller activity excreted after a weekend or after a non-working period, typical of certain compounds. In some cases, as for example ^{131}I, the urinary excretion functions diminish by orders of magnitude within a few days, and therefore the choice of the time pattern of intake can influence the assessed dose by that same order of magnitude.

The information on the working history is very important. For long-lived nuclides, the amount present in the body and the amount excreted depends on the time the individual has been exposed. Following a chronic intake of 1 Bq per day of type S ^{232}Th, 5 days a week, its concentration in the lungs after 20 years of work is expected to increase by a factor of 4.4 in relation to the concentration after one year of work, for both AMAD 5 micron and 1 micron. On the other hand, the concentration excreted in the feces is supposed to be constant throughout that time period.

The software accepts the input of a series of data points from bioassay results collected at different times after intake and determines the best estimate of an intake using a least squares fit, maximum likelihood fit, or Bayesian approach. Thus, multiple data points may be used to estimate the actual intake, as specified in item 5.1 of OCAS-IG-02. The software will also determine the best estimate of an intake from information on different monitoring techniques, e.g. urine, fecal, and in vivo monitoring. The simultaneous use of multiple data from different monitoring techniques may be used as a tool to infer the route(s) of intake and the date(s) of intake and in refining preliminary estimates of intake (items 4.1.2 , 5.1 and 6.5 of OCAS-IG-02).

If bioassay data are not adequate to evaluate the individual's internal dose, workplace monitoring data will be used, if available, as specified in item 5.2 of OCAS-IG-02. All recommendations in item 5.2 will be followed to determine the concentration of the radionuclide in the breathing zone

and to estimate the workers' intake. If physical-chemical characteristics of the aerosol are not known, ICRP default parameters will be used. Organ doses will be calculated using ICRP CD-ROM, *The ICRP Database of Dose Coefficients: Workers and Members of the Public*, Version 2.01, Elsevier Science Ltd., 1998.

The same applies to the estimation of doses using information on the source term, as specified in item 5.3 of OCAS-IG-02. The software used for calculating organ doses from bioassay measurement may also be used for calculating organ doses from calculated intakes. It will be used to calculate doses when the use of specific absorption factors from lungs to blood is necessary (item 4.3 of OCAS-IG-02).

The software is thus a very efficient tool to perform blind reviews of internal doses in accordance with OCAS-IG-02. All guidelines contained in the document will be followed: the ICRP models; the collection of data for the individual case; the calculation of the dose to the organ or tissue of interest, including the correlation of ICD-9 Codes to ICRP Models; the collection of work area data; the collection of the individual dosimetry data; the preliminary dose estimates and the detailed dose estimates that include the estimate of the date of intake; the estimation of the uncertainty in the internal dose calculation; the treatment of missed doses; and the estimation of radon and progeny doses. All information given in the examples for item 8.0 will be used.

3.6.2 Dose Per Unit Measured Activity in the Body or in the Excreta: A Tool to Minimize Uncertainties

When multiple data points from bioassay monitoring collected at different times after intake or resulting from different bioassay monitoring methods are used to estimate the dose, the fitting procedure chosen for the analysis is very important. In a recent intercomparison among the most recently developed software that utilizes the most current ICRP models, a discrepancy was noted related to the different methods of fitting to calculate the best estimate of the intake and dose. The second reason for the discrepancy was due to the level of expertise and the choice made by the user on "reasonable" assumptions such as particle sizes; choice of solubility types as exemplified in item 4.3 of OCAS-IG-02; treatment of rogue data, as exemplified in item 5.1 of OCAS-IG-02; weight given to some bioassay results or to a particular bioassay method; etc. ["Review of Methods and Computer Codes for Bioassay Data Interpretation," E.Ansoborlo, P.Bérard, M. Bailey, V. Berkovski, A. Birchall, F. Fry, R. Guilmette, G. Miller, N. Ishigure, J. Lipsztein, and D.Nosske, presented at the Workshop on Intakes of Radionuclides, Oxford, UK, 2002, which will be published in 2003 in "Radiation Protection Dosimetry."] Thus, we should not be surprised if we find different dose estimates from the same data, unless very specific instructions are given in the Task Order. Alternatively, these issues could be addressed as part of the uncertainty analysis in the reconstructed doses.

Tabulations and graphs of dose per unit-measured activity (in the body or in excreta) at specified times after intake will be used. The variable dose per unit measured bioassay quantity is obtained using the most recent published ICRP dosimetric and metabolic models. Those tabulations and graphs are very helpful in determination of the best estimate of a dose (organ dose or effective dose) from results collected at different times, or from different monitoring techniques, e.g., urine, fecal, and direct measurements data. For example, for some

radionuclides, graphs of doses as a function of lung absorption Type and AMAD reveal "areas of invariance," i.e., time periods where the assessment of dose is relatively insensitive to assumptions made about lung absorption Types and AMAD. Thus, in dose reconstruction analysis, when AMAD and/or lung absorption Types are not known or are poorly defined, the use of monitoring data, if available, in the period of time corresponding to the invariance area, can minimize parameter uncertainties.

Those graphs are also useful for assigning a weight to multiple bioassay results, e.g., using the criteria of weighting data according to sensitivity in relation to dose calculations. The weight to multiple bioassay result will also depend on the specific organ for which dose is calculated, e.g., urine is best correlated to systemic organs. These correlations are also well visualized in the mentioned graphs.

The graphs may be used for defining the uncertainties related to an unknown or poorly defined model parameter. The graphs of dose per unit measured activity also provide a tool to rapidly compare doses derived from the same data set of bioassay results, using different assumptions. Thus, the choice of the hypothesis that leads to the greatest dose is easily visualized and determined.

3.6.3 Basic Approach to External Dose Reconstruction Reviews

For external dose radiation exposure, OCAS-IG-001 provides guidance on the methods of dose reconstruction. The procedures for blind reviews will be exactly the ones specified in OCAS-IG-001. As specified in this document, the three groups of workers who require dose reconstruction are: workers who were not monitored, workers who were monitored inadequately, and workers whose monitoring records are incomplete or missing.

Among the workers that were monitored inadequately, special technical attention will be given to the results from individual monitoring done in early times, when the sensitivity and accuracy of the dosimeters were inadequate as compared to modern standards (items 1.1.3, 2.2.1 and 2.3.1,OCAS-IG-001). We anticipate considerable uncertainties in the evaluation of low energy photon dose, mixed photon field evaluation, electron dosimetry and neutron dosimetry.

For the Dosimeter Photon Dose (item 2.1.1.2), the evaluation of external photon doses using film dosimetry is straightforward for photon energies above 250 keV. In this region, the energy dependence of the film emulsion is quite low. It was, and still is, usual to perform the calibration of the dosimetric system using only a high-energy source of photons (above 250 keV). Unless the dosimetric system was characterized and calibrated for low energy photons, the evaluation of external dose due to exposure to, for example, the plutonium isotopes, will be compromised. The review of the individual monitoring reported doses for plutonium workers will include, where possible, an evaluation of the calibration, evaluation, and dose reporting procedures. For example, if the dose due to 17 keV photons was evaluated using the net optical density under the lead filter, and not through the "open window dose" the lower limit of detection will be much higher than 30 millirem (mrem), and probably closer to 500 mrem. This would increase the "missing dose" for these cases.

In the cases in which a worker handled, in the same monitoring period, two or more radionuclides that emit both high and low photon energies, the evaluation of the external photon dose using photographic dosimetry becomes more difficult. For early dosimetric systems, it is possible that only the high energy or only the low energy component of the dose was reported. Again, if the calibration, evaluation, and dose reporting procedures are available, the uncertainty in the dose estimates may be assessed. With the advent of LiF TLD monitoring systems, this problem no longer exists due to the lower energy dependence of LiF.

To evaluate the organ dose, it is necessary to discriminate the energy spectrum of the photon field into the three energy bands established in OCAS-IG-001. The evaluation of dose through film dosimetry or TLDs normally requires the previous evaluation of the average energy of the photon field that is being measured. This energy is, however, not always reported together with the dose. In these cases, it is necessary to determine the radionuclide or radionuclides the worker handled over the monitoring period to determine the relevant energy spectrum. The determination of the relative distribution using the site relative inventory or the review of historical operations is recommended in item 2.1.1.2 of OCAS-IG-001.

As for the neutron dose (item 2.2, OCAS-IG-001), even today, neutron dosimetry is subject to large uncertainties. The main problem is that film and TLD neutron dosimeters have a large energy dependence, together with the fact that the energy range of neutron fields is huge (a few eVs to many MeVs—around seven orders of magnitude). The dosimeter may be typically calibrated for one energy spectrum, and to the others a "calibration factor" was applied. Even today, an uncertainty of + 100% and - 50% for any neutron dose, would be considered an "acceptable result." All procedures recommended in item 2.2 of OCAS-IG-001 will be followed. The OCAS-IG-001 document defines five energy ranges for neutron fields. The establishment of the neutron field energy spectrum is therefore important for the calculation of the organ dose. All data available will be carefully analyzed. All sources of complementary data will be used, for example, neutron energy spectrum studies made at a number of work places using Bonner Spheres and published in the literature. These studies might even be applied to early dates if conditions remained the same. Another example is the use of the ratio of neutron to gamma dose in workplace situations for which it has been well-established. Also, when TLD techniques were used to determine the neutron dose, the photon dose was also evaluated and should have been recorded. In these cases, the ratio can serve as an estimate of the missing neutron dose for cases when the neutron source geometry and the laboratory moderation are relatively unchanged and where only the photon dose was evaluated and recorded.

For electron dose reconstruction using film dosimeter records (item 2.3.1, OCAS-IG-001), it is important to determine whether the worker was also exposed to low energy (15 - 25 keV) photon fields, as these can leave an image similar to an electron irradiation on film dosimeters. Although the calibration process and energy dependence of the film emulsion lead to uncertainties in the electron dose evaluation process, the main source of uncertainty is due to the short range of electrons in air and clothing and the irradiation geometry. For example, consider a worker doing decontamination work and directly handling a source of beta-gamma radiation. The electron dose registered on the thorax dosimeter would be quite low, and the electron dose to the skin of the thorax could be considered zero due to the shielding of the worker's clothing. However, the electron dose to the hands would be much greater, and, unless reliable extremity

dosimetry was provided, a better estimate of the electron dose may be obtained through source term investigations.

For the Photon Dose Reconstruction from a Source Term (item 3.1.3, OCAS-IG-001), it is advisable to use a computer program, as specified in item 3.1.3.2, OCAS-IG-001. We will use NIOSH recommended software. If the Task Order does not specify particular software, we will use a program that uses a voxel phantom to simulate the human body and the Monte Carlo technique to provide the organ doses for external photon fields in the energy range of 15 keV - 2 MeV. The program simulates the source of the radiation, which can be of a complex geometry, and the shielding, which can include many layers of different material. Using the Monte Carlo technique, self-shielding and build-up are taken into account. The use of voxel phantoms is the most modern accepted technique for the simulation of the whole body and is derived from whole body magnetic resonance image (MRI) scan. The program reports the absorbed dose to each organ and tissue relevant to the calculation of the effective dose as defined in ICRP 60. Ground sources or cloud sources may be simulated. The phantom may be placed in a standing, sitting, lying, or other geometry in relation to the source. Although the program simulates multi-energy photon emission and integrates the dose in each relevant tissue over all energies, it can also be used to determine the Hp(10) dose and the photon energy spectrum arriving at the voxel phantom, and therefore permit the application of the Dose Conversion Factors tabled in Appendix B of OCAS-IG-001. The software may be applied to find the "worst case geometry."

There are few programs that have all characteristics described above. They are currently used in different laboratories, but most of them are not commercially available. We will use software that has been extensively benchmarked against other Monte Carlo programs for simple geometries, and against physical phantoms with TLDs for more complex geometries. However, this will only be done with the approval of the Task Order. All guidelines contained in document OCAS-IG-001 will be used.

Currently, we are inclined to derive the effective dose and organ dose using anthropomorphic phantoms with the specified ICRP tissues and organs and the radiation transport code, MCNP4C. Modified (to include the esophagus and skin) versions of the Pacific Northwest National Loaboratory male and female MIRD-like anthropomorphic phantom will be used for the calculations. These modified phantoms are similar to the Adam and Eva phantoms developed in 1982 at Germany's National Research Center for Environment and Health, GSF.

The anthropomorphic phantoms consist of three principal sections: an elliptical cylinder representing the arms, torso and hips; two truncated circular cones representing the two legs and feet; and an elliptical cylinder representing the neck region and lower portion of the head, which is topped by half an ellipsoid. The gonads and eyes are specified. The arms are not separated from the torso, and minor appendages such as fingers, feet, ears, chin and nose are omitted. Internal organs are approximated by simple mathematical equations describing the average shapes and sizes.

Each internal organ is considered to be homogeneous in composition and density. Different compositions and densities are used for the lungs, skeleton, and the total body minus the skeleton

and lungs. The breasts and esophagus have the same composition as the total body minus the skeleton and lungs, with different densities.

The red bone marrow (RBM), a very important tissue to consider, is difficult to represent mathematically due to the intricate mixture of RBM and bone in the skeleton. In this analysis, the composition of the skeleton will be regarded as a homogeneous mixture of true bone and marrow. The RBM will be assumed to absorb energy per gram as efficiently as the bone. The dose to the RBM will be determined by taking the sum of the percentages of RBM found in the different bones. These values are available in MIRD Pamphlet No. 5.

The source type, energy, and geometry (volume, planar, point, etc.) will be modeled from available information. Conservative approximations will be assumed if information regarding the source geometry is unavailable. The most conservative irradiation geometry (usually AP-PA depending on source type and energy) as well as the most likely irradiation geometry will be used for the calculations.

The organ doses will be calculated in the phantom using the energy deposition tally in MCNP4C. Once all of the organ doses are known, the effective dose can also be calculated using the appropriate ICRP tissue and radiation weighting factors.

3.7 Special Exposure Cohort Petition Reviews

The SEC is a specific group of employees defined by Congress in the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) who are eligible for compensation under this Act. They are defined by the proposed rule 42 CFR 83 as follows:

> *. . .employees of DOE, DOE contractors or subcontractors, or Atomic Weapons Employers (AWEs) who worked an aggregate of at least 250 days before February 1, 1992 at a gaseous diffusion plant in (1) Paducah, KY, (2) Portsmouth, OH, or (3) Oak Ridge, TN and who were monitored using dosimetry badges or worked in a job that had exposures comparable to a job that is or was monitored using dosimetry badges; or (4) employees of DOE or DOE contractors or subcontractors employed before January 1, 1974 on Amchitka Island, AK and exposed to ionizing radiation in the performance of duty related to the Long Shot, Milrow, or Cannikin underground nuclear tests.*

If any of these employees had or has been diagnosed with one of 22 specified cancers, then they or their survivors will receive a "lump sum payment of $150,000 and prospective medical benefits" as compensation for illness which resulted from these radiation exposures. These individuals are automatically eligible for compensation and do not have to undergo dose reconstruction under 42 CFR 82 in order to determine PC of their cancers. Proposed rule 42 CFR 83, "Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort under the Energy Employees Occupational Illness Compensation Program Act of 2000: Notice of Proposed Rulemaking," describes the petition process that is being developed for the addition of employees of other DOE facilities and AWEs to the SEC. Addition to the SEC

depends primarily on the ability of NIOSH to perform a dose reconstruction under 42 CFR 82. The EEOICPA states that a class of employees may be considered part of the Cohort if:

> *HHS determines that (1) it is not feasible to estimate with sufficient accuracy the radiation dose that the class received; and (2) there is a reasonable likelihood that such radiation dose may have endangered the health of members of the class.*

Individuals or groups seeking to be added to the SEC must submit a petition to the DOL. Categories of petitions are described in 42 CFR 83 as follows:

> *(1) Petitions from claimants in which NIOSH has already determined that a dose reconstruction cannot be completed under 42 CFR 82. These petitioners only need to cite this decision in their petitions, since NIOSH has already compiled an administrative record for this class of employees. The petitioners are not required to provide any additional information. These petitions are considered the highest priority;*
>
> *(2) Petitions from employees who have not submitted a claim for dose reconstruction under 42 CFR 82. These petitions are considered the second highest priority;*
>
> *(3) Petitions from claimants who are currently waiting for results from dose reconstruction under 42 CFR 82. These petitions are considered low priority.*

The EEOICPA indicates that the Advisory Board will independently review a small sample of petitions evaluated by NIOSH. These audits will allow the Board to oversee the work being done by NIOSH. As prescribed by the proposed SEC rule and guided by the Board, the basis for a worker to be considered a member of a class of workers for purposes of this sampling review would include (but not be limited to):

- Range of uncertainty in doses for the workers for which data are available. This will include factors such as missing and faulty data, measurement uncertainties, and incomplete data. For example, at Fernald, group doses have been calculated with low uncertainty, but the same data indicate uncertainties that are very large for individual workers. A review would include an evaluation of the statistical procedures by which the best dose estimate is assigned to a worker who does not have any or adequate data for a reliable dose reconstruction to be done.

- How closely job descriptions fit the actual work done by workers. In some cases, workers had particular job designations, but in practice performed other duties as well.

- Degree to which facility reviews show that the particular worker consistently performed the work described for which relatively reliable dose reconstruction cases are available.

- Time period for which data are available compared to the period for which the worker in question worked a particular job.

- Whether a worker also performed other jobs that are not typical of those who are members of a group for whom dose data are available.

- Solubility information regarding the chemical form of radionuclides to which a particular worker or group of workers were exposed.

- How frequently bioassay data were taken for individual workers or for workers belonging to the group from which dose for an individual might be imputed.

- When, how much, and in what form, recycled uranium was processed or present, and whether data exist from which the transuranic and fission product contamination of the recycled uranium can be determined or reasonably inferred.

- Handling of film badges and use of correction factors.

The checklist presented in Exhibit 3-2 provides a systematic review of the above considerations and other specific information that SC&A proposes to use in performing these reviews. However, **this checklist is simply a guideline** and may not contain all of these elements that can and may be used for an audit. Each petition, and the information required for its review, will be considered on a case-by-case basis. A "Comments" section is provided in the checklist if the auditor chooses to elaborate or describe information which is not contained in the checklist.

The need to combine both a systematic review of criteria, such as that contained in the checklist, with expert judgment of the radiological dosimetry and operation history of a facility can be illustrated at any number of DOE sites.

For example, at Fernald, "blowouts" occurred in furnaces at Fernald, where UF_4 was reduced to U metal. Workers present during blowouts or who were given the job of cleanup immediately afterwards (if they were from the production area) might be in a different subcategory than the other production workers in this area. Witness information can be useful not only in determining unusual accidents, but also for determining accidents and process upsets that were not so unusual, but nonetheless not part of the planned normal production process. Another example of this kind of problem would be uranium chip fires, which were prevalent at a number of DOE sites handling uranium metal.

At Los Alamos TA-33 (Tritium Facility), workers frequently lacked respirator protection while working in tritium-contaminated atmospheres. When significant exposures occurred, some workers would expedite urinary excretion by consuming large amounts of liquids; others would delay routine bioassay monitoring. Exposure would vary by the particular job being performed, the individual worker's work practice, and ventilation present in the work area at the time. The only area monitoring was an area tritium alarm set at relatively high activity levels. A determination of the ability to reconstruct these doses would hinge on a combination of witness interviews, historic area alarming data, and available dose records, and a judgment on their