U.S. Department of Energy
Office of River Protection
P.O. Box 450
Richland, Washington 99352

04-ESQ-044

Mr. E. S. Aromi, President
and General Manager
CH2M HILL Hanford Group, Inc.
Richland, Washington 99352

Dear Mr. Aromi:

CONTRACT NO. DE-AC27-99RL14047 – REQUEST FOR ACTION ON ASSESSMENT OF COMPUTER SOFTWARE QUALITY ASSURANCE

This letter forwards the results of the U.S. Department of Energy (DOE), Office of River Protection assessment of CH2M HILL Hanford Group, Inc. (CH2M HILL) control of computer software for the Hanford Tank Farms during the period of April 19 through 26, 2004. The assessment team (Team) identified nine Findings (Attachment 1) and made five Observations. The details of the assessment, including the Observations, are documented in the assessment report (Attachment 2).

The Team found the Contractor had a coherent program for the control of computer software that generally conformed to both the CH2M HILL contract and a set of assessment criteria established for the DOE complex. However, there were a number of problems with implementation of the program. The assessors noted the following positive characteristics of the program:

- The Contractor made considerable progress in bringing its software quality assurance program into compliance with DOE and industry standard requirements;

- The Contractor used Lockheed Martin Information Technologies, Inc., to perform a comprehensive comparison of existing safety software to the requirements of NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities," Subpart 2.7;

- The program was documented through generally appropriate procedures; and

- When Contractor personnel recognized a problem they reacted promptly to document and resolve it.

Despite these characteristics, some software was not adequately controlled by the Contractor and its subcontractors. The Team identified nine Findings characterizing the following issues:

- Spreadsheets with relatively complex macros and add-in programs were not properly classified, were not adequately tested, and did not have adequate configuration management;

- A subcontractor, Fluor Federal Services (FFS), did not document the required information about computer software used in engineering calculations. The requirements for documenting the information were not implemented in FFS's quality assurance program, and the supplier

evaluation that qualified FFS for safety work did not identify the deficiencies;

- Another subcontractor allowed its maintenance agreement for a commercial design code to expire and was not receiving error notices. The subcontractor was using an outdated release of the code that had uncorrected errors;

- A computer code named MicroShield®, identified by the Contractor as quality-affecting software (QAS), was not tested prior to use. MicroShield® was used to calculate values for the design of radiation shielding;

- Some personnel using QAS, as well as some personnel responsible for administration of QAS, were not adequately trained on software quality assurance requirements and processes; and

- The Contractor's independent and management assessment programs either did not identify or did not successfully resolve these issues before they were identified by the Team.

The Observations discussed in Attachment 2 do not identify deficiencies but represent experience-based Observations of the Team members that CH2M HILL should consider as a source of information for improving its program. In addition to responding to the Findings in accordance with the attached Notice of Finding, CH2M HILL should state the actions it intends to take as a result of Observations.

If you have any questions, please contact me, or your staff may call Robert C. Barr, Director, Office of Environmental Safety and Quality, (509) 376-7851.

Sincerely,

Roy J. Schepens
Manager

ESQ:DHB

Attachments: (2)

cc w/attachs:
P. M. Bubar, EM-3
R. H. Lagdon, EM-41
C. Defigh-Price, CH2M HILL
E. R. Hamm, CH2M HILL
R. L. Higgins, CH2M HILL
M. L. McElroy, CH2M HILL
R. L. Nelson, CH2M HILL

W. L. Smoot, CH2M HILL
L. M. Morgan, NRE

Notice of Findings

The responsibilities of CH2M HILL Hanford Group, Inc. (CH2M HILL) as they relate to the Quality Assurance (QA) requirements of CH2M HILL's scope of work, are defined in the River Protection Project Tank Farm Contract, Part I – The Schedule, Section H, H.30 "Quality Assurance System." H.30 states "The Contractor shall develop and implement a company specific Quality Assurance Program (QAP), supported by documentation that describes its overall implementation of QA requirements." The QAP shall be developed based on:

- Title 10 Code of Federal Regulations (CFR) Part 830.122 for all nuclear facilities and projects within the scope of that document;

- DOE O 414.1A, "Quality Assurance," requirements for facilities and projects not within the scope of 10 CFR 830.120; and

- Office of Civilian Radioactive Waste Management "Quality Assurance Requirements and Description," DOE/RW-0333P, for those elements of CH2M HILL's scope of work that involves the interim storage of spent nuclear fuel and high-level radioactive waste.

CH2M HILL's QA program is defined in TFC-PLN-02, "CH2M HILL Hanford Group Quality Assurance Program Description." Implementing procedures describe processes to meet the requirements described in CH2M HILL's Quality Assurance Program Description (QAPD).

During performance of an assessment of CH2M HILL's programs for control of design and analysis computer software, conducted April 19 - 26, 2004, at CH2M HILL's offices, the U.S. Department of Energy; Office of River Protection (ORP) identified nine Findings.

Finding 01 – The Fluor Federal Services, Inc. (FFS) quality assurance program and procedures did not implement some requirements of NQA-1 for documenting the use of computer software in design work.

Requirements:

1. TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.7.2.1 states, "Procurement documents for items or services shall contain the following information, as applicable… Quality assurance program requirements applicable to the scope of work. These requirements shall be applied commensurate with the importance and/or complexity of the item or service and based on requirements from NQA-1 or other national or international standards for quality assurance that meet and implement the requirements of 10 CFR 830.122, and that ensure the supplier provides products and services of the requisite quality."

2. FFS contract #FFS-1709-17, Revision 1, dated April 11, 2000, "Requirements (Including Quality Assurance Requirements)" states, "FFS shall document, implement, and maintain a quality assurance program, which is consistent with applicable criteria of NQA-1 (see Attachment 2)." Attachment 2 of this document, "Quality Assurance Requirements (NQA-1)," states, "The ANSI/ASME NQA-1 requirements and supplements below apply to this procurement… 3S-1 Design Control"

3. ASME NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities," Mandatory Supplement 3S-1, "Supplementary Requirements for Design Control," Section 3.1, "Design Analysis," states, "Documentation of design analyses shall include … Identification of any computer calculation, including computer type, computer program (e.g., name) revision identification, … evidence of or reference to computer program verification, and the bases (or reference thereto) supporting application of the computer program to the specific physical problem."

Discussion

The assessment team reviewed a sample of design calculations performed using computer software and found some did not identify computer type, evidence of or reference to computer program verification, or the bases supporting the application of the program to the physical problems. These were requirements of NQA-1, Supplement 3S-1, which was specified in the contract between FFS and CH2M HILL. The calculations were performed by FFS. Calculations performed by other subcontractors evaluated by the assessors included the required information. The assessment team found that these requirements were not implemented in either the FFS quality assurance manual or the FFS engineering calculation procedure.

When asked about the missing information, CH2M HILL and FFS provided objective evidence that the required actions were actually performed, but the evidence was not in the form of records. Therefore, when the project was completed, the evidence would no longer be available.

The assessors based their conclusions on the following:

- There was no formal record of the computer type, evidence of or reference to computer program verification, or the bases supporting the application of the program to the physical problems for the following engineering calculations performed by FFS:

  – Calculation No. W314-P-062, dated February 25, 2000, "Buried Piping SN631, SN632, and DR100 Pipe Stress Analysis;"

  – Calculation No. W314-P-029, dated February 4, 2003, "Buried Piping Analysis – 3" – SN-635 and 3" SN-633;"

  – Calculation No. W314-P-058, dated January 29, 2003, "Buried Piping Analysis SN633 & SN635 Pipe Support Analysis;" and

  - Calculation No. W314-P-063, dated May 22, 2000, "Buried Piping SN631, SN632, SN633 & SN635 and Pipe Support Stress Analysis."

- FFS Practice 134 000 1100, May 1, 2002, "Quality Management Program," did not implement the requirement of NQA-1, Supplement 3S-1, that stated, "Documentation of design analyses shall include … Identification of any computer calculation, including computer type, computer program (e.g., name) revision identification, … evidence of or reference to computer program verification, and the bases (or reference thereto) supporting application of the computer program to the specific physical problem."

- FFS Practice 134 200 1020, March 1, 2002, "Engineering Calculations," did not implement the requirement of NQA-1, Supplement 3S-1, cited above.

Finding 02 – The supplier evaluation of FFS did not identify FFS's failure to implement some requirements.

Requirements:

TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.7.2.4 stated, "Prospective suppliers shall be evaluated to verify their capability to meet performance and schedule requirements."

Discussion:

Based on the supplier evaluation for FFS conducted by Fluor Hanford, Inc., Acquisition Verification Services (AVS) organization, AVS placed FFS on the Hanford Site Evaluated Suppliers List (ESL). The ESL stated that FFS satisfactorily implemented the requirements of NQA-1-1994, Supplement 3S-1, "Supplementary Requirements for Design Control," however the current ORP assessment found that some requirements were not implemented. Specifically, some requirements of Supplement 3S-1, Section 3.1, for documenting the use of computer programs in design analyses were not implemented.

Finding 03 – Some personnel using quality-affecting software were inadequately trained in software quality assurance requirements and procedures.

Requirements:

TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.2.3.1.2 stated, "Training shall include general criteria, including applicable codes, standards, and company procedures; applicable quality assurance program elements; job responsibilities and authority; and technical objectives as related to the job function."

Discussion:

While most individuals working with safety software displayed an understanding of software quality assurance (SQA) requirements and procedures, some individuals working with other software defined by CH2M HILL as quality-affecting software did not display this understanding. Specifically, CH2M HILL had not provided personnel working with MicroShield® with SQA training, and these individuals did not understand the required processes. For example, they did not understand the requirement to submit to the Production Readiness Review Board (PRRB) a "PRRB Submission Package" when the Software Quality Checklist item 20, "Will the software reside on or and be accessed from the HLAN?" Checklist item 20 was marked, "Yes," but a PRRB Submission Package was never prepared.

Also, checklist item 20 was incorrectly marked, "Yes," because only the installation files for MicroShield® were located on the HLAN. The installation files were to be downloaded and the program installed on local work stations. The code was then accessed from the work station, not the HLAN.

Finding 04 – Subcontractors performing an evaluation of double shell tank dome-loads in a staff-augmentation role used software that was not controlled under the CH2M HILL SQA program.

Requirements:

1. TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.7.2.4.6 states, "Suppliers/contractors providing direct support services used for staff augmentation shall work to CH2M HILL's quality assurance program, and they do not have to be evaluated for placement on the ESL."

2. Statement of Work "C-2," Req. #: 97798, Revision 0, "Comparative Study of ANSYS® Finite Element Models for SST and DST Tanks," Section 7.3 states, "The Supplier/Subcontractor is providing direct support services and shall work under the CHG Quality Assurance Program Description (TFC-PLN-02) and the applicable implementing procedures." (This contract applied to work performed by M&D Associates, Inc.)

3. Statement of Work "C-2," Req. #: 92879, Revision 0, "Development of ANSYS® Finite Element Models for SST and DST Tanks," Section 7.3 states, "The Supplier/Subcontractor is providing direct support services and shall work under the CHG Quality Assurance Program Description (TFC-PLN-02) and the applicable implementing procedures." (This contract applied to work performed by JLR Engineering Solutions, Inc.)

Discussion:

CH2M HILL contracted M&D Associates, Inc. to evaluate baseline models for single-shell and double-shell tanks using the ANSYS® computer code, and to develop finite element models for the actual field condition of the tanks. CH2M HILL also contracted JLR Engineering Solutions, Inc., to develop finite element models of the tanks to help confirm the analysis of record. In both cases, the contracts specified that personnel would work in staff augmentation roles and follow CH2M HILL procedures. However, the copies of the ANSYS computer code used by these subcontractors were controlled using their own processes, not by CH2M HILL procedures. Neither subcontractor was evaluated for placement on the Hanford ESL, so the quality of their procedures was unknown.

While the quality of the procedures and processes used for the subcontracted work was unknown, CH2M HILL personnel said they checked the subcontractors' work by running corroborating analyses with a copy of ANSYS controlled using CH2M HILL procedures.

Finding 05 – Software quality assurance documentation for some codes was incomplete.

Requirements:

1. TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.6.2.2.3.a stated, "The development, procurement, installation, and use of computer software as applicable to the design, construction, operation, modification, repair, and maintenance of CH2M HILL's nuclear facilities, including safety analysis, shall be a controlled process."

2. TFC-BSM-IRM_HS-C-01, Revision A-4, "Software Development, Implementation, and Management," Section 4.3.1, "Quality Affecting Software," stated, "Develop a Software Quality Assurance Plan … Submit the Functional Design Requirements to the CIO for approval … Approve the Software Quality Assurance Plan."

3. TFC-BSM-IRM_HS-C-01, Revision A-4, "Software Development, Implementation, and Management," Section 4.1.2 states, "Complete Functional Design Requirements … defining critical features, capabilities, and interfaces to be included in the required software applications."

Discussion:

For software identified as "legacy software," CH2M HILL procedures required completion of a "Software Quality Checklist" followed by preparation of a software quality assurance plan and other documents. The assessment team reviewed these documents for a sample of codes and found they were not always complete. The missing documentation may represent required quality assurance activities that were not completed. The assessors noted CH2M HILL did not have an inventory of quality-affecting software and software documentation to address all

quality-affecting software. This made it difficult for them to assure themselves all required activities were performed and documents were completed. The following are examples of documentation issues:

- There were no test plans or test reports for either Version 5.x or 6.x of MicroShield®;

- The functional design requirements documents for MicroShield® Versions 5.x and 6.x ended at the executive summary. They did not address much of the information required by TFC-BSM-IRM_HS-C-01;

- Shortly before this assessment, CH2M HILL found that they did not prepare the required software quality assurance plan for ANSYS®. This was documented in Problem Evaluation Report (PER) 2004-2192;

- PER 2003-0428, dated January 24, 2003, identified the lack of an inventory of quality affecting software, but it was closed out on February 27, 2003. Closure was based on the availability of the HISI database as a repository for this information, but this database was not intended to encompass all quality-affecting software; and

- As described elsewhere in this Notice of Finding, spreadsheet templates used in safety applications did not have the required Spreadsheet Verification Forms or life-cycle documentation.

Finding 06 – A CH2M HILL subcontractor was not obtaining error notices for AutoPIPE® software and had not upgraded to a version that corrected some errors.

Requirement:

NQA-1-1994, Supplementary Requirements 3S-1, Section 3.1 states, "Computer programs shall be controlled to assure that changes are documented…"

Discussion:

ARES Corporation (ARES) performed work for CH2M HILL using several design and analysis computer codes, including AutoPIPE®. The Fluor Hanford Acquisition Verification Services organization verified that ARES had a quality assurance program that conformed to specific requirements of NQA-1-1994, including the supplementary requirements of 3S-1. However, the assessors found that ARES was not obtaining error notifications from the vendor of AutoPIPE®. Also, ARES was using Version 6.1 of the code rather than Version 6.2. Version 6.2 was released in October 2002 to correct errors.

When asked about this, ARES managers stated that their maintenance contract with the vendor expired, but they had not been aware of this. When the assessors brought this problem to the

attention of CH2M HILL and ARES management, they initiated action to obtain the error notices (approximately 200) and begin evaluating them for impact on completed work.

Finding 07 – The assessment and corrective action management systems did not assure that software quality assurance issues were comprehensively identified and resolved.

Requirements:

1. TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.10.2.1 stated, "Independent assessments shall be planned and conducted to measure item and service quality and adequacy of work performed in complying with applicable ESH&Q requirements, and to determine the effectiveness of implementation and to promote improvement."

2. TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.9.2.1.1 stated, "Managers at every level, using approved procedures, shall plan, schedule, and conduct assessments of their management systems and processes that are important to achieving objectives."

3. TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.3.3.1 stated, "Processes to detect, correct, and prevent quality problems shall be developed and implemented. Deficiencies in items, services, and processes, shall be reported in a timely manner to appropriate levels of management."

Discussion:

While CH2M HILL had appropriate processes and procedures for identifying, reporting, resolving, and verifying correction of conditions adverse to quality, these processes did not identify and correct all of the problems subsequently found during the current ORP assessment. In some cases the problems were identified previously by CH2M HILL, but corrective actions did not effectively resolve the issues.

CH2M HILL conducted independent assessments of computer software quality assurance that identified some meaningful issues. The last independent assessment was conducted by the QA organization less than one year before this ORP assessment, and CH2M HILL conducted another assessment approximately one year before that. However, neither assessment identified problems like the failure to provide the required testing and documentation of spreadsheet templates identified by this ORP assessment.

Earlier assessments performed by CH2M HILL identified problems that should have been corrected but were found again during the current ORP assessment. The following are examples of these issues.

- The CH2M HILL assessment program did not identify the problems with the control of calculational spreadsheets used in safety applications found by this ORP assessment;

- A May 2003 CH2M HILL management assessment found that the MicroShield® software was not verified and validated in accordance with company procedures. This problem was documented in PER-2003-2063, but the current ORP assessment found that MicroShield® still did not have the required test plan and test report required to document its fitness for use;

- CH2M HILL independent assessment RPP-A-03-01, dated May 6, 2003, found several applications for which the required software quality assurance plans were not prepared. This condition was documented in PER-2003-1589, and was finding No. 2 of the CH2M HILL assessment. In preparing for the current ORP assessment, CH2M HILL found that there was no software quality assurance plan for ANSYS®. CH2M HILL documented this in PER-2004-2192 the day before the assessors began fieldwork for this assessment.

- An Observation in CH2M HILL independent assessment RPP-A-03-01 identified the need for a company-wide inventory of quality-affecting software. This issue was documented in PER-2003-1448. PER-2003-1448 was later closed out, even though no inventory of software was created. While there was no requirement to maintain such an inventory, the PER documented a weakness in the CH2M HILL software quality assurance program that was not resolved by the PER. When the assessors brought this issue to the attention of CH2M HILL, they documented the problem in PER-2004-2192.

Finding 08 – The required testing and configuration control of software was not always performed and documented.

Requirements:

1. TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.6.2.2.3 stated, "The development … and use of computer software as applicable to the … safety analysis [of] nuclear facilities, shall be a controlled process. Software verification and validation activities shall:

   - "Ensure that the software adequately and correctly performs all intended functions;"

   - "Ensure that the software does not perform any unintended function that either by itself or in combination with other functions can degrade the entire system;"

   - "Software verification and validation activities shall be planned and performed for each system configuration, which may impact the software;" and

   - "The results of software verification and validation activities shall be documented …"

2. TFC-ENG-CHEM-D-33, Revision B, "Spreadsheet Verifications," stated:

   - "Prior to relying on the results of a spreadsheet, verification of spreadsheet formulae is required for all single or multiple use spreadsheets;" (Paragraph 4.1)

   - "Document the spreadsheet methodology, including the equations used for all calculations, in accordance with [the CH2M HILL engineering calculation procedure];" (Paragraph 4.1.3)

   - Steps 4.1.5 through 4.1.25 describe documentation of spreadsheets through the use of the "Spreadsheet Verification Form;" and

   - "For multiple use spreadsheets, protect the spreadsheet structure … and protect the cell formulae against inadvertent change…" (Paragraph 4.1.14.a)

3. TFC-BSM-IRM_HS-C-02, Revision A-1, "COTS Software Acquisition, Implementation, and Management," Section 4.2 states:

   - "Identify test requirements…"

   - "Assign test personnel to perform testing…"

   - "Develop a software Test Plan…"

   - "Test software and security measures in accordance with the approved Test Plan;" and

   - "Prepare a Test Report…"

Discussion:

The assessors found several reusable software templates used in safety applications that were not controlled in accordance with CH2M HILL software quality assurance requirements. The templates did not have the Spreadsheet Verification Forms that are required by CH2M HILL to document testing and other verification activities. Templates containing or calling macros and other applications containing executable code did not have software quality assurance plans, system requirements specifications, and other required life-cycle documentation. The configuration of spreadsheet templates available on servers for reuse was not controlled to assure testing and documentation would remain valid. The assessors also found at least one commercial off-the-shelf (COTS) quality-affecting software application that was not tested in accordance with CH2M HILL procedures. The following problems led the assessors to their conclusion:

- The following reusable templates required either "Spreadsheet Verification Forms" or full life-cycle quality assurance documentation, but lacked both:

    - Flammable Gas Waste Group Assignment;

    - Waste Tank Volume Rebaseline;

    - In-Tank Vehicle Fuel Fire;

    - Ventilation System Filtration Failures; and

    - Aboveground Structure Failure Accident.

- The reusable spreadsheet template, OCD-015, existed in several versions at multiple locations on Hanford Local Area Network servers. One version still on the server was known to have errors and the revision replacing it, also on the server, had not been tested and approved. The spreadsheet was not protected in accordance with CH2M HILL procedures.

- There was no test plan or test report for the COTS application, MicroShield®. Personnel using the code said they did not perform the tests required by CH2M HILL procedures.

Finding 09 – The Contractor did not have an explicit error reporting process that required documenting errors, notifying users, notifying vendors, and verifying completed work was still valid.

Requirements:

1. TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.6.2.2.3.c stated, "Procedures governing the control of software shall meet the consensus industry standards for software control …"

2. NQA-1-2000, Subpart 2.7, Section 204 stated, "Method(s) for documenting, evaluating, and correcting software problems shall … describe the evaluation process, … define responsibilities … [The] method shall provide … for how the error impacts past and present use, … how the users are notified …, and how to avoid the error pending implementation of corrective action."

3. TFC-PLN-02, Revision A-3, "Quality Assurance Program Description," Section 2.5.2.1 stated, "All activities that can affect the quality, safety, or the environment of CH2M HILL products and services shall be prescribed by, and performed, in accordance with documented, management-approved procedures, instructions, and design documents that meet the requirements of applicable regulatory requirements, DOE orders, technical standards, and administrative controls."

Discussion:

The only explicit process for software error reporting described in Contractor procedures was in TFC-BSM-IRM_HS-C-02, Revision A-1, "COTS Software Acquisition, Implementation, and Management." However, this procedure did not require that problems be documented, provided no process for notifying users, and did not require evaluation of impact on ongoing or completed work. Cognizant CH2M HILL representatives said that problems would be reported and managed in the Problem Evaluation Request (PER) system. However, users interviewed by the assessors said they would not necessarily report software problems with a PER.

The Contractor's QAPD established a general requirement that software control procedures will meet consensus standards, but did not identify the consensus standards. In the absence of a CH2M HILL specification, the assessment team concluded the appropriate consensus standard for error reporting was NQA-1, Subpart 2.7. Contractor procedures for error reporting did not meet the requirements of this standard.

ORP requests that CH2M HILL provide, within 30 days from the date of the letter that transmitted this Notice, a reply to the Findings above. The reply should include: 1) admission or denial of the Findings; 2) the causes of the Findings, if admitted, and if denied, the reason why; 3) the corrective steps that have been taken and the results achieved; 4) the corrective steps that will be taken to avoid further Findings; and 5) the date when full compliance with the applicable commitments in your QAPD will be achieved. Where good cause is shown, consideration will be given to extending the requested response time.

U.S. DEPARTMENT OF ENERGY
Office of River Protection
Environmental Safety and Quality

ASSESSMENT:	Control of Tank Farms Contractor Design and Analysis Computer Software
REPORT:	A-04-ESQ-TANKFARM-006
FACILITY:	CH2M HILL Hanford Group, Inc.
LOCATION:	Richland, Washington
DATES:	April 19 - 26, 2004
ASSESSORS:	David H. Brown, DOE-ORP, Lead Assessor Shivaji S. Seth, DOE-RL Assessor Clifford A. Ashley, DOE-RL, Assessor William Dey, Bechtel National, Inc., Assessor
APPROVED BY:	P. P. Carier, Verification and Confirmation Official

Executive Summary

Introduction

From April 19 - 26, 2004, the U.S. Department of Energy (DOE), Office of River Protection (ORP) assessed the implementation of the Tank Farm Contractor's program for controlling design and analysis computer software. The Contractor for the operation and maintenance of the Tank Farms is CH2M HILL Hanford Group, Inc., (CH2M HILL). The assessment team (Team) evaluated the control of safety software used in the design and analysis of safety systems, structures, and components. This included software used by the Contractor in design and analysis work as well as software used by subcontractors. The Team also reviewed some computer software that was defined by the Contractor as "quality-affecting software" (QAS) that was not classified as safety software. The Team used criteria, review, and approach documents (CRAD) provided by the DOE Office of Assistant Secretary for Environmental Safety and Health to guide its review of the following areas:

- Verification and Validation;
- Software Design Descriptions;
- Software Requirements Descriptions;
- User Documentation;
- Software Quality Assurance;
- Software Procurement;
- Software Problem Reporting and Corrective Actions; and
- Software Configuration Management.

Significant Conclusions and Issues

The Team found the Contractor had a coherent program for the control of computer software that generally conformed to both the CH2M HILL contract and the CRADs. However, there were a number of problems with implementation of the program. The assessors noted the following positive characteristics of the program:

- The Contractor made considerable progress in bringing its software quality assurance program into compliance with DOE and industry standard requirements;
- The Contractor used Lockheed Martin Services, Inc., to perform a comprehensive comparison of existing safety software to the requirements of NQA-1, Subpart 2.7;

- The program was documented through generally appropriate procedures; and

- When Contractor personnel recognized a problem they reacted promptly to document and resolve it.

Despite these characteristics, some software was not adequately controlled by the Contractor and its subcontractors. The Team identified nine Findings characterizing the following issues:

- Spreadsheets with relatively complex macros and add-in programs were not properly classified, were not adequately tested, and did not have adequate configuration management;

- A subcontractor, Fluor Federal Services (FFS), did not document the required information about computer software used in engineering calculations. The requirements for documenting the information were not implemented in FFS's quality assurance program, and the supplier evaluation that qualified FFS for safety work did not identify the deficiencies;

- Another subcontractor allowed its maintenance agreement for the code, AutoPIPE®, to expire and was not receiving error notices. The subcontractor was using an outdated release of the code that had uncorrected errors;

- A computer code named MicroShield®, identified by the Contractor as QAS, was not tested prior to use. MicroShield® was used to calculate values for the design of radiation shielding;

- Some personnel using QAS, as well as some personnel responsible for administration of QAS, were not adequately trained on software quality assurance requirements and processes; and

- The Contractor's independent and management assessment programs either did not identify or did not successfully resolve these issues before they were identified by the Team.

In addition to these Findings, the Team identified several issues that it classified as Observations. Observations are issues based on opinions of the Team rather than contractual non-compliances. ORP may request a response from the Contractor on Observations. The Observations addressed the following issues:

- The Contractor should consider revising the Quality Assurance Program Description (QAPD) to implement the requirements of NQA-1, Subpart 2.7. At the time of the assessment, the QAPD did not identify a specific requirements base for the Contractor's software life-cycle process;

- The Contractor should assure that all necessary safety analyses performed by the previous contractor, Fluor Hanford, Inc., (FHI) for the 242-A Evaporator and the 222-S Laboratory were adequately controlled. An earlier DOE assessment of FHI software found inadequacies in the control of software used in the development of fire hazard analyses and documented safety analyses;

- The Contractor should consider establishing authorized user lists for QAS. Without authorized user lists, it is difficult to assure compliance with several software quality assurance requirements; and

- The Contractor should consider establishing software use logs. This would be a valuable tool in identifying potentially defective work in the event that an error is identified that could affect completed work.

Table of Contents

List of Acronyms

ARES	Ares Corporation
AVS	Fluor Hanford, Inc., Acquisition Verification Services
CH2M HILL	CH2M HILL Hanford Group, Inc.
CFR	Code of Federal Regulations
CIO	Chief Information Officer
COTS	Commercial-Off-the-Shelf
CRAD	Criteria, Review, and Approach Document
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
ESL	Evaluated Suppliers List
FAI	Fauske and Associates, Inc.
FFS	Fluor Federal Services, Inc.
FHI	Fluor Hanford, Inc.
HISI	Hanford Information System Inventory
HLAN	Hanford Local Area Network
IT	Information Technology
JLR	JLR Engineering Solutions, Inc.
LMIT	Lockheed Martin Information Technologies, Inc.
M&D	M&D Associates, Inc.
OCRWM	DOE Office of Civilian Radioactive Waste Management
ORP	U.S. Department of Energy, Office of River Protection
PER	Problem Evaluation Request
PNNL	Pacific Northwest National Laboratory
PRRB	Production Readiness Review Board (for the HLAN)
QA	Quality Assurance
QAP	Quality Assurance Program
QAPD	CH2M HILL Quality Assurance Program Description
QAS	Quality-Affecting Software
SCM	Software Configuration Management
SDD	Software Design Description
SQA	Software Quality Assurance
SRD	Software Requirements Description
SRS	System Requirements Specification
TWINS	Tank Waste Information Network System
V&V	Verification and Validation

Control of Tank Farms Contractor Design and Analysis Computer Software for the Period of April 19 - 26, 2004

Assessment Purpose and Scope

The assessment team compared the Contractor's processes for the control of design and analysis software to the criteria specified in the U.S. Department of Energy (DOE) Office of Assistant Secretary for Environmental Safety and Health Criteria, Review, and Approach Document (CRAD) 4.2.4.1, Revision 3, "Assessment Criteria and Guidelines for Determining the Adequacy of Software Used in the Safety Analysis and Design of Defense Nuclear Facilities" and the Contractor's Quality Assurance Program Description (QAPD)[1]. The CRAD was prepared in response to Defense Nuclear Facilities Safety Board recommendation 2002-1, "Quality Assurance for Safety Software at Department of Energy Defense Nuclear Facilities."

Significant Observations and Conclusions

The assessors found CH2M HILL Hanford Group, Inc. (CH2M HILL) and its subcontractors used several commercial off-the-shelf software (COTS) safety software packages but had relatively little custom safety software. Custom safety software was in the form of Microsoft Excel spreadsheet and Mathcad calculational software templates. Some calculational software could be verified completely with each use, and so did not require life-cycle documentation. Other calculational software was retained in the form of templates because it was too complex to fully verify with each use or was available for repetitive use. Some of the templates reviewed by the assessors were made available on a Hanford Local Area Network shared drive to Engineering personnel who applied the template applications in safety applications. The safety applications included development of the documented safety analysis (DSA). Some template applications were relatively complex, using add-in applications that called, for example, Monte Carlo algorithms. These were software applications for which CH2M HILL procedures required life-cycle quality assurance documentation and configuration control.

While CH2M HILL staff made use of some COTS codes, the majority of work using computer design and analysis was performed by subcontractors using COTS software. The assessors visited the offices of two subcontractors performing Tank Farms work and evaluated their software quality assurance practices. These were Fluor Federal Services, Inc., (FFS) and ARES Corporation (ARES). These firms worked under their own quality assurance programs and were listed on the Hanford Evaluated Suppliers List (ESL). They were placed on the ESL based on supplier evaluations performed by the Fluor Hanford, Inc., (FHI) Acquisition Verification Services (AVS) organization.

[1] TFC-PLN-02, Revision A-3, *Quality Assurance Program Description*

The assessors also reviewed the work of two subcontractors whose contracts specified they would perform their duties in a staff augmentation role. Their work was to perform calculations determining acceptable dome loading on waste tanks. The subcontractors were M&D Associates, Inc. (M&D) and JLR Engineering Solutions, Inc. (JLR).

The assessment team reviewed the use of some COTS software controlled and used by the Contractor. While not considered by the Contractor to be safety software within the definition of the CRAD, it was still defined by CH2M HILL as "quality-affecting software" (QAS). Contractor procedures required all life-cycle quality assurance documentation for QAS, regardless of whether or not it was safety software. In this area, the assessors focused their attention on the code MicroShield®, which was used to calculate radiation shielding design values.

The assessors also reviewed the Tank Waste Information Network System database as a sample of databases with nuclear safety implications and reviewed the history of software quality assurance (SQA) oversight within CH2M HILL.

The Contractor documented its quality assurance program in TFC-PLN-02, Revision A-3, "Quality Assurance Program Description." The QAPD stated that its requirements were based on American Society of Mechanical Engineers NQA-1-1989, "Quality Assurance Program Requirements for Nuclear Facilities" (NQA-1). While the QAPD addressed computer software, it drew its explicit software control requirements from NQA-1, Supplement 3S-1, "Supplementary Requirements for Design Control," and Supplement 11S-2, "Supplementary Requirements for Computer Program Testing." It did not invoke the requirements of Subpart 2.7, "Quality Assurance Requirements for Computer Software for Nuclear Facility Applications." NQA-1 defined the software life-cycle in Subpart 2.7, including specifying the documentation required to assure conformance to life-cycle controls. Instead of drawing requirements from Subpart 2.7, the QAPD included the following statement: "Procedures governing the control of software shall meet the consensus industry standards for software control…" Contractor managers and staff said this meant software life-cycle quality assurance procedures were required to conform to some standard, and personnel preparing procedures could select from NQA-1, Subpart 2.7; Institute of Electrical and Electronics Engineers, Inc., standards; or other consensus standards for requirements.

While the Contractor did not explicitly invoke the life-cycle quality assurance requirements of NQA-1, Subpart 2.7, it had the Hanford Site information technology contractor, Lockheed Martin Information Technologies, Inc., (LMIT) compare its safety software to the requirements of Subpart 2.7. For each code identified by CH2M HILL as safety software, LMIT issued an individual report documenting the review.

The assessment team concluded the following:

Software Requirements Descriptions (SRD)

SRDs are used to assure that a given code is appropriate for its use. This is particularly important during the development of new software when complete and unambiguous requirements are necessary to define the problems to be addressed by the new software. This assessment found that the Contractor had appropriate procedures governing SRDs. However, some of the software templates developed and used by the Contractor in safety work did not have the required software life-cycle quality assurance documentation, including SRDs. This issue was documented in Finding A-04-ESQ-TANKFARM-006-F05.

The safety analysis and design software applications, such as HADCRT® and ESP®, developed by CH2M HILL's subcontractors, had adequate software requirements descriptions. (Assessment Note A-04-ESQ-TANKFARM-006-03.)

Software Design Descriptions (SDDs)

The Contractor had appropriate procedures governing SDDs. However, some relatively complex spreadsheet template applications developed by the Contractor documented some, but not all, design information. The assessors concluded that additional design information was needed to adequately justify the custodianship and use of such software template applications. This issue was documented in Finding A-04-ESQ-TANKFARM-006-F05.

The few software applications developed by CH2M HILL's subcontractors had adequate design descriptions. (Assessment note A-04-ESQ-TANKFARM-006-02.)

User Documentation

The Contractor established and implemented requirements for software user documentation that met the CRAD criteria. Most safety codes were well-established COTS products with user documentation that met expectations of the vendors' customers. Installation processes were defined and documented, while user manuals contained sufficient information to guide trained personnel in the use of the software. However, user documentation did not exist for the software templates used by CH2M HILL in safety work.

CH2M HILL and its subcontractors did not establish specific requirements for training and qualification of personnel using more complex applications, such as ANSYS®, AutoPIPE®, and MicroShield®. Also, they did not establish qualified user lists. Vendors for most of these codes provided training, and some users attended the training. The Team concluded that the Contractor and its subcontractors should consider identifying training and qualification requirements for these codes and identify trained individuals on qualified user lists. Requirements should be properly tailored to the technical complexity of the software, providing an objective basis for

qualifying users and maintaining status of their qualification and training and retraining, as necessary. This issue was documented in Observations A-04-ESQ-TANKFARM-006-O04 and O05. (Assessment note A-04-ESQ-TANKFARM-006-04.)

Software Verification and Validation

The Contractor software quality assurance procedures adequately addressed the criteria described in DOE's CRAD for validation and verification (V&V) of design and analysis software. However, Contractor personnel did not always comply with these procedures. This issue was documented in Finding A-04-ESQ-TANKFARM-006-F08.

In a sample of approximately six spreadsheets used in support of the Tank Farm DSA that were reviewed by the Team, none had the "Spreadsheet Verification Forms" required by Contractor procedures. This included both single-use spreadsheets to be verified for each use and multiple-use templates that Contractor staff said were also verified at each use. Contractor staff referred to the templates as "tools," meaning that all results for each use would be independently verified.

Some software templates (primarily spreadsheets) developed in support of the Tank Farm DSA invoked operations from add-in and external applications that performed relatively complex operations, such as uncertainty analysis applying the Monte Carlo method. These templates were not fully and independently verified. For example, one such template for Flammable Gas Waste Group Assignment was checked only for a bounding case using an alternate calculation method. CH2M HILL procedures specified software applications with these characteristics required V&V and life-cycle quality assurance documentation.

The COTS application, MicroShield®, was used regularly to analyze radiation shielding configurations, but Contractor staff said the required testing was not performed.

The CH2M HILL subcontractor, FFS, used the COTS application, FLUENT®, to perform calculations used in safety work but did not use a sufficiently accurate method for V&V testing. The acceptance criteria used by FFS required visual comparisons of relatively complex graphical results, but the assessment team considered this method did not provide the accuracy required to properly validate the code. (Assessment note A-04-ESQ-TANKFARM-006-01.)

Software Configuration Management (SCM)

CH2M HILL and its subcontractors had appropriate processes for configuration management of safety software. However, Contractor staff did not always follow their procedures and the assessors found configuration management deficiencies. For example, two versions of the same spreadsheet template used in safety applications were available on a shared drive. One of the versions had not been tested, while the other version had errors and was outdated. Also, contrary to CH2M HILL procedures, users could modify formulas and code in software templates, negating any testing and SCM controls on the templates. Contractor managers believed the

software templates were protected from modification, but the Team pulled up the templates and found they were not protected. This issue was documented in Finding A-04-ESQ-TANKFARM-006-F08.

The Contractor did not maintain an inventory of all quality-affecting software. Such an inventory would have allowed them to identify the missing software quality assurance plans and other documentation deficiencies identified in this assessment.

The Contractor did not have a process for software usage logs, as is the case for some other contractors. While not a requirement, software use logs would be a valuable tool in identifying potentially defective work in the event that an error is identified that could affect completed work. This issue was documented in Observation A-04-ESQ-TANKFARM-006-O02. (Assessment note A-04-ESQ-TANKFARM-006-08.)

Software Quality Assurance

The Contractor established and implemented an SQA program that, although adequate for many of the CRAD evaluation criteria, fell short of providing comprehensive assurance of software quality. Most of the procedures were sufficiently detailed and, when correctly executed, provided assurance that SQA activities and software practices were appropriate and complete.

The requirements base for the Contractor's QAPD did not explicitly use NQA-1, Subpart 2.7. This is an important consensus standard defining the software life-cycle. Instead, the QAPD contained a very general statement that procedures should conform to national and consensus standards. (The Team noted that Contractor software quality assurance procedures were generally consistent with Subpart 2.7.) The Team concluded that the Contractor should consider implementing requirements from NQA-1, Subpart 2.7 through the QAPD. This issue was documented in Observation A-04-ESQ-TANKFARM-006-O01.

The Contractor's procedures did not require the necessary software quality assurance training be provided to personnel responsible for control and maintenance of software. This issue was documented in Finding A-04-ESQ-TANKFARM-006-F03.

This assessment identified issues that were previously identified and closed by CH2M HILL but were not adequately resolved. It also identified additional issues the Contractor did not identify, but should have. A more aggressive program of independent and management assessments would have found and corrected the problems identified in this assessment. This issue was documented in Finding A-04-ESQ-TANKFARM-006-F07.

FFS did not document all computer software information required by NQA-1 in calculation packages. This included information such as version of the software, reference to V&V of the software, and justification for using a particular code to solve a specific problem. While this information existed, it was not documented in the required record and was not being retained. The NQA-1 requirement to document this information was not implemented in FFS's quality

assurance program, and the supplier evaluation of FFS by the FHI AVS organization did not identify this noncompliance. These issues were documented in Findings A-04-ESQ-TANKFARM-006-F01 and F02.

Two subcontractors performing an evaluation of waste tank dome loads in staff-augmentation roles for CH2M HILL used computer programs that were not controlled under the CH2M HILL quality assurance program. These subcontractors were M&D and JLR. The subcontractors used copies of ANSYS® that were licensed to, and controlled by, their own organizations, when they should have been using a copy controlled by CH2M HILL. The Contractor had not requested the FHI AVS organization to evaluate either M&D or JLR, so the compliance to standards of their software quality assurance programs was unknown. This issue was documented in Finding A-04-ESQ-TANKFARM-006-F04.

An earlier DOE assessment of computer software control at FHI found inadequacies in the control of software used in fire hazard analyses and documented safety analyses. FHI responded to the Finding by issuing unreviewed safety question documents for each FHI facility. The authorization basis documents for the 222-S Laboratory and the 242-A Evaporator were developed and maintained by FHI before they were transitioned to CH2M HILL. When the Team brought this to the attention of CH2M HILL management, they documented the issue and initiated action to assure the DSAs for the 222-S Laboratory and the 242-A Evaporator were technically adequate with respect to analyses performed by computer. This issue was documented in Observation A-04-ESQ-TANKFARM-006-O03. (Assessment note A-04-ESQ-TANKFARM-006-05.)

Software Procurements

CH2M HILL and its subcontractors established and implemented quality assurance programs that met the CRAD criteria. The programs included evaluation of suppliers to assess their capabilities to provide software and services satisfying specific requirements associated with defined tasks and scopes of work. They also included requirements that vendors provide notifications of software errors. (Assessment note A-04-ESQ-TANKFARM-006-06.)

Software Problem Reporting and Corrective Action

The Contractor established requirements for software problem reporting and error correction through the Problem Evaluation Request (PER) system and the procedure for managing COTS software. However, the PER process did not explicitly invoke software quality assurance requirements and did not assure all required actions would be taken. Neither error reporting process assured that all users would be notified, that vendors would be notified, or that impact on work potentially affected by errors would be evaluated. This issue was documented in Finding A-04-ESQ-TANKFARM-006-F09.

NQA-1, Subpart 2.7 identifies the nuclear industry standard for software error reporting. The Contractor rarely invoked NQA-1, Subpart 2.7 in contracts, so the Contractor rarely required subcontractors to have an error reporting and resolution process. However, the subcontractors evaluated by this assessment did have appropriate systems for error reporting and resolution.

In one situation, ARES inadvertently allowed a maintenance contract to expire and was not receiving error notifications for the associated code. Also, ARES was not using a newer version of the code that corrected previously identified errors. When the assessors brought this problem to the attention of ARES and CH2M HILL management, ARES obtained approximately 200 error notices and evaluated their impact on completed work. This issue was documented in Finding A-04-ESQ-TANKFARM-006-F06. (Assessment note A-04-ESQ-TANKFARM-006-07.)

List of Items Opened, Closed, and Discussed

Opened

A-04-ESQ-TANKFARM-006-F01	Finding	The FFS quality assurance program and procedures did not implement some requirements of NQA-1 for documenting the use of computer software in design work.
A-04-ESQ-TANKFARM-006-F02	Finding	The supplier evaluation of FFS did not identify FFS's failure to implement some requirements.
A-04-ESQ-TANKFARM-006-F03	Finding	Some personnel using quality-affecting software were inadequately trained in software quality assurance requirements and procedures.
A-04-ESQ-TANKFARM-006-F04	Finding	Subcontractors performing an evaluation of double-shell tank dome-loads in a staff-augmentation role used software that was not controlled under the CH2M HILL SQA program.
A-04-ESQ-TANKFARM-006-F05	Finding	Software quality assurance documentation for some codes was incomplete.
A-04-ESQ-TANKFARM-006-F06	Finding	A CH2M HILL subcontractor was not obtaining error notices for

		AutoPIPE® software and had not upgraded to a version that corrected some errors.
A-04-ESQ-TANKFARM-006-F07	Finding	The assessment and corrective action management systems did not assure that software quality assurance issues were comprehensively identified and resolved.
A-04-ESQ-TANKFARM-006-F08	Finding	The required testing and configuration control of software was not always performed and documented.
A-04-ESQ-TANKFARM-006-F09	Finding	The Contractor did not have an explicit error reporting process that required documenting errors, notifying users, notifying vendors, and verifying completed work was still valid.
A-04-ESQ-TANKFARM-006-O01	Observation	The Contractor should consider revising the QAPD to implement the requirements of NQA-1, Subpart 2.7.
A-04-ESQ-TANKFARM-006-O02	Observation	The Contractor should consider establishing software usage logs.
A-04-ESQ-TANKFARM-006-O03	Observation	The Contractor should assure that all necessary safety analyses performed by the previous contractor for the 242-A Evaporator and the 222-S Laboratory were adequately controlled.
A-04-ESQ-TANKFARM-006-O04	Observation	The Contractor should consider establishing authorized user lists for quality-affecting software.
A-04-ESQ-TANKFARM-006-O05	Observation	The Contractor should specify training and qualification requirements for use of some codes.

Closed

None

Discussed

None

Signatures

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Clifford A. Ashley, DOE-RL
Assessor

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Assessor

Appendix A

Team Member Biographies

David H. Brown, Assessment Team Leader – Mr. Brown has been leading and participating in quality assurance assessments for 17 years. Several of these have included or been focused on computer software quality assurance. He has been certified as a Lead Auditor in accordance with the requirements of NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities," since June 1987. Mr. Brown holds a baccalaureate degree in nuclear science from the State University of New York, Maritime College (1971). He received formal training in computer software quality assurance from the Pacific Northwest National Laboratory in 1992. He participated in development of the following U.S. Department of Energy (DOE) directives and documents:

- The DOE response to Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 2002-1, "Quality Assurance for Safety Software at Department of Energy Defense Nuclear Facilities;"

- Criteria and Review Approach Document (CRAD) 4.2.3.1, "Criteria and Guidelines for the Assessment of Safety System Software and Firmware at Defense Nuclear Facilities;"

- CRAD 4.2.4.1, "Assessment Criteria and Guidelines for Determining the Adequacy of Software Used in the Safety Analysis and Design of Defense Nuclear Facilities;" and

- DOE-STD-1172-2003, "Safety Software Quality Assurance Functional Area Qualification Standard."

Dr. Shivaji S. (Shiv) Seth, Assistant Assessment Team Leader – Dr. Seth is Senior Technical Advisor for Nuclear Safety at the DOE Richland Operations Office. He has reviewed the nuclear safety authorization basis and the operational safety of several nuclear facilities at the Hanford Site, including those where safety software is deployed both in safety systems and in analyzing facility safety. As a member of a DOE team responding to DNFSB Recommendation 2002-1, Dr. Seth was a contributor to the development of the DOE qualification standard for software engineers and the CRADs for safety software assessments.

Prior to joining DOE in 1996, Dr. Seth managed and guided safety and systems engineering projects at the MITRE Corporation in support of the U.S. Nuclear Regulatory Commission (USNRC) and DNFSB. He was the principal investigator of a major project for the USNRC for developing the guidelines, technical basis, and research needs for high-integrity (safety) software in nuclear power plant safety systems. This work (NUREG/CR-6263) has been cited as a resource in various USNRC Regulatory Guides.

Dr. Seth's 35 years of work in the nuclear field also includes nuclear reactor core design and analysis, optimization of the reactor fuel cycle, and safety and probabilistic risk analyses. These involved considerable programming and use of computers. His experience at a national laboratory includes planning and analyzing reactor critical experiments for investigating the design and safety of fast reactors and supervising reactor operations. These involved the use of digital instrumentation and control systems.

Dr. Seth holds Master's and Doctor's degrees in nuclear engineering from the Massachusetts Institute of Technology, Cambridge, Massachusetts, and has authored over 80 technical publications.

Clifford A. Ashley, Assessor – Mr. Ashley has been leading and participating in quality assurance assessments and surveillances during the last 13 years for DOE. This includes nine years experience as a DOE Facility Representative, as well as service as subject matter expert and various quality assurance positions with the New Production Reactor Project and the Tank Waste Remediation System Project. Several assessments included or were focused on computer software quality assurance.

During 1979 to 1981, Mr. Ashley's primary responsibility was to program a HP-1000 computer to record and extract critical test data from Department of Defense sidewinder missile servomechanisms.

Mr. Ashley holds a baccalaureate degree in electrical engineering from Washington State University (1975), and a Master of Science degree in Electrical Engineering from North Dakota State University (1976).

William C. (Bill) Dey, Assessor – Mr. Dey is a Senior Quality Assurance Engineer with Bechtel National, Inc., and has participated in computer software quality assurance audits, both internal and external to Bechtel. His 12 years of experience in the commercial nuclear industry includes assessment and repair of irradiated fuel elements, fuel performance analysis and reporting, cost estimating, preparation of proposals and contracts, and development of software tools to support these activities.

Mr. Dey holds a baccalaureate degree in chemical engineering from Oregon State University (1985).

Appendix B

Assessment Notes