

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES 1/35

CORRECTIVE ACTION REQUEST

CAR No: 97-03

Associated AR, SR, NCR No: CNWRRA Audit Report 97-01

PART A: DESCRIPTION OF CONDITION ADVERSE TO QUALITY

Contrary to the requirements of TOP-018, paragraph 5.7, two versions of the TPA Code, Version 3.0, were delivered to the NRC on two different days prior to the official release date (4/16/97) which indicated completion of all requirements. In addition, the Software Requirements Description (SRD) was not prepared prior to significant development or modification of the codes as required by paragraph 5.3.1. This code has been rejected by the NRC as not meeting commitments made in the CNWRA HLW Operations Plans. The TPA code was not clearly identified as a Beta version and use of the code by the NRC for informal analyses could present problems in traceability and configuration control.

J.C. Trbovich

Initiated by: T.C. Trbovich

Date: June 12, 1997

PART B: PROPOSED ACTION

Responsible EM: **B. Sagar**
Response Due: **8/1/97**

1) Extent of Condition:

See attached pages.

2) Root Cause:

See attached pages.

3) Remedial Action:

See attached pages.

Proposed Completion Date: **NA**

4) Corrective Action to Preclude Recurrence:

See attached pages.

Proposed Completion Date: **NA**

Element Manager:

Bruce Sagar

Date: **8/1/97**

PART C: APPROVAL

Comments/Instructions

Director of QA:

Samuel Malachuk

Date: **8/1/97**

PART D: VERIFICATION OF CORRECTIVE ACTION IMPLEMENTATION

1) A comprehensive Lessons Learned paper was written by the CNWRA president and sent to the NRC 10/30/97. 2) NRC accepted TPA Version 3.1; see NRC correspondence of 10/21/97. 3) TOP-018 Revision Committee has made recommendations. 4) TOP-018 is in process of being revised and is covered under CAR 97-02. Ben

Distribution:

EMs
Directors
W. Patrick

Verified by:

J.C. Trbovich

Date: **11/26/97**

6125198

PART B: PROPOSED ACTION

The CAR describes a condition adverse to quality that comprises four parts. These are (i) two versions of TPA Version 3.0 code were delivered to the NRC prior to the release date of April 16, 1997; (ii) the SRD was not prepared prior to significant development or modifications of the code; (iii) the code released was not clearly identified as a beta version; and (iv) the NRC rejected the code as not meeting commitments made in the CNWRA OPS. In the following, each component part is analyzed.

1) Extent of Condition:

- (i) Two versions of TPA Version 3.0 code were sent to the NRC staff prior to the release date of April 16, 1997, as a part of collegial interaction which is the normal way of working between the NRC and CNWRA staffs. In past years, the NRC staff were co-developers of the code and anticipated playing a similar role regarding TPA Version 3.0. Several NRC staff are involved in coding and testing TPA Version 3.1. During code development, the delivery of the code to the NRC is in the context of obtaining their assistance in development.
- (ii) While several drafts of the SRD were prepared and informally discussed with the NRC PEM at the time, the SRD was not approved until much later when significant code development had already occurred. Just prior to the formal approval of the SRD, the NRC considered whether to go back to the old version of the code or continue with the new one. It is indicative of the significant extent of the work that had been done that NRC management made the decision to continue development of the new code despite their stated misgivings.
- (iii) Each version of the code sent to the NRC was identified in the code and on the output files; however, evidence for this was not presented during the audit (hence this part of the finding). Furthermore, the version and state of development of the code were not clearly indicated in correspondence that transmitted the codes to NRC. The practice of identifying each version of the code continues to be followed as work toward completion of TPA Version 3.1 progresses.
- (iv) The code was rejected by the NRC for several reasons. First, the changes to the code were far more extensive than the NRC expected or understood based on their understanding of the SRD and related communications with CNWRA staff. Second, the NRC HLW Board was pressured into accepting an approach that was contrary to previous decisions made by the Board. In February 1997, the Board was confronted with making a decision to either go back to the old version of the code or continue with the development of the new one. In view of the significant effort put in code development, they decided to continue with the new version, but had not fully bought into the approach. Third, the involvement of the NRC staff in deciding on the conceptual models for the code and other critical decisions was not adequate. Fourth, too little time was allowed in the schedule between NRC approval of the SRD (i.e., the middle of February) and the completion date for the code (i.e., March 17, 1997) to produce a quality code. However, CNWRA failed to recognize this and bring it to the attention of NRC management in a timely manner.

2) Root Cause:

- (i) This approach should not be considered a problem, because interaction with the NRC staff must (in general) include two-way transfer of codes prior to official release. This is particularly important when the NRC and CNWRA staff are jointly developing a code. The practice of clearly identifying such codes will be followed in the future.
- (ii) The root cause for this part of the CAR is the necessity felt by the CNWRA code developers that to meet the March 17, 1997, date for completion of the code, development had to be started immediately—before formal approval of the SRD could be obtained. The earlier drafts of the SRD were not sufficient to inform the client of the extensive changes that were envisioned by the CNWRA to the code. For example, TPA Version 3.0 had a different architecture from that of Version 2.0, requiring extensive new coding. Even though the functionality was similar to Version 2.0, the extent of the change was not explicit in the SRD.
- (iii) The evidence of adequate labeling should have been produced during the audit. Furthermore, identification of the status of the code in transmittal documentation would have aided timely and effective communication, which would have mitigated or avoided the ultimate rejection of the code (see item iv).
- (iv) The root cause for the rejection of the code by the NRC was their determination that (a) the changes to the code were far more extensive than the NRC required or wanted; (b) the NRC staff was not adequately involved in the code development activity; (c) the code delivered on March 17, 1997, did not meet NRC expectations of the code being ready for use in sensitivity analyses. Further analysis of the causes underlying rejection of the code are noted in items 1)(ii) through 1)(iv) and 2)(ii) of this analysis.

3) Remedial Actions:

- (i) No remedial action is suggested, although clarification of the current practice in the procedure may be appropriate. Continue and enhance interactions at all levels of the NRC staff and management.
- (ii) The root cause is being addressed in developing TPA Version 3.1. Discussions with the NRC staff have been enhanced significantly to remedy the situation. Also, a test plan for Version 3.1 is being followed and twice a week coordination meetings between the code testers/developers are held.
- (iii) Continue to clearly identify each version of the developing code as these are exchanged between the NRC and CNWRA staff. Indicate the status and version numbers of codes in transmittal correspondence.
- (iv) Teams have been formed to achieve agreement on the conceptual model, mathematical formulation, and basecase data for each module of the TPA code. NRC staff and management are directly involved in these teams and the agreements reached are being thoroughly documented. Furthermore, the CNWRA and NRC Management reviews the progress of Version 3.1 on a

weekly basis. With the greater involvement of the NRC staff, there is a greater sense of ownership of the code on the part of the NRC staff. Consequently, the risk of the NRC rejecting Version 3.1 has been substantially reduced.

4) Corrective Action to Preclude Recurrence:

- (i) See item 3)(i).
- (ii) Code development activity will be limited to exploratory activity that would assist in developing a good SRD prior to full understanding between code authors and clients is reached with respect to the SRD. This will be clarified in TOP-018, which will require SRD approval before code development is started. For a major code development activity such as TPA-3.0, an estimate of resource requirements and schedule will be developed (on a module level) and agreed to between CNWRA management and the client. The client will be informed of possible problems and delays on a regular and timely basis.
- (iii) See item 3)(iii).
- (iv) For an activity like the development of the TPA code, the NRC staff and management will be involved from the beginning. Plans for code development will be developed with module teams clearly identified. Even if the functionality of the code is agreed to, the client will be informed of any changes in code architecture and the extent to which new code will be written. A relatively detailed SRD will play a crucial role in assuring agreement prior to commencement of code development effort. In a large code development exercise like the TPA, timely warning of potential delays in code development will be provided to management.

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October 30, 1997
Contract No. NRC-02-97-009
Account No. 20-1402-158

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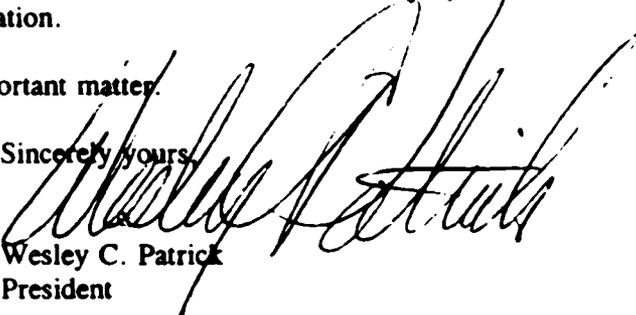
Subject: Total-System Performance Assessment Code Development Lessons Learned Analysis

Dear Mrs. Meehan:

Enclosed is the subject Total-System Performance Assessment (TPA) code development lessons learned analysis. This document was prepared by the Center for Nuclear Waste Regulatory Analyses (CNWRA) to fulfill a commitment I made during the July 15, 1997, NRC Center Review Group (CRG) meeting to conduct the analysis and provide NRC with a copy of the results.

This analysis was prepared as part of the ongoing process of evaluating, monitoring, and taking remedial actions concerning problems that arose during development and distribution of TPA Version 3.0 and its successors. To avoid duplication of efforts and in an attempt to achieve a reasonably consistent understanding of what occurred and why, this analysis drew from the annual quality assurance audit of the CNWRA, work on Corrective Action Request 97-03 that was generated by that audit, the deliberations of a process improvement team that was formed to reexamine TOP-018 "Development and Control of Scientific and Engineering Software," the results of an independent analysis by a member of the SwRI Software Engineering Department, limited independent interviews of key CNWRA staff and management, consideration of the internal NRC lessons learned on this subject, and reviews of pertinent program documentation. For convenience, the reader may refer to section 2 of the enclosed analysis for a concise summary and conclusions of the investigation.

Please contact me if you have any questions regarding this important matter.

Sincerely yours,

Wesley C. Patrick
President

/bsc

- cc: J. Greeves
- M. Federline
- J. Austin
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**EVALUATION AND LESSONS LEARNED REGARDING
DEVELOPMENT OF THE TOTAL-SYSTEM PERFORMANCE ASSESSMENT CODE**

October 1997

1 INTRODUCTION

The purpose of this document is to provide a concise evaluation of the factors that led to the production and delivery of a computer code — the Total-System Performance Assessment (TPA) code, Version 3.0 — that did not meet the requirements of the U.S. Nuclear Regulatory Commission (NRC), who sponsored the work. The objectives of the evaluation and analysis are twofold: (i) identify the root causes of the problems that occurred and (ii) make recommendations regarding how to avoid recurrence of this and similar problems.

This document addresses both Corrective Action Request (CAR) 97-03, which was generated as a result of the Quality Assurance (QA) Audit 97-01, and broader management concerns regarding development and distribution of the TPA code that have been expressed in both written correspondence and numerous meetings between the NRC and the CNWRA.

2 SUMMARY AND CONCLUSIONS

The complexity of development of the TPA Version 3.0 code and its successors and the large number of people involved produced a full spectrum of perspectives regarding the problems that led to rejection of the code by the NRC. Taking into consideration all of those perspectives, this lessons learned was able to identify a series of recommendations that will both mitigate the current problem and minimize the likelihood of its recurrence. Implementation of many of these recommendations is already in progress and early success — particularly with regard to NRC staff participation and effectiveness of communications — is being observed.

Participation of NRC Staff in Development

- All NRC-funded code development should be undertaken as a joint effort of the NRC and CNWRA staffs.

Accuracy and Consistency of the Planning Process

- The scope of work for complex activities such as computer code development should be more clearly and completely defined prior to undertaking such activities.
- The schedules and budgets should be carefully reviewed and evaluated to ensure that they are consistent both with the defined scope of work and similar previous development activities.
- The CNWRA should be proactive in addressing potential inaccuracies and inconsistencies among scope, schedule, and budget.

Communication and Dissemination of Information

- A team approach should be followed, with the NRC and CNWRA staff and KTI leads being actively included in all aspects of future NRC-funded code development work, commencing with conceptualization and continuing through preproduction testing.
- Specific reviews by contractor and client staff and management should be conducted at appropriate points during SRD preparation, code development, and code modification.
- Available vehicles for enhancing communication should be more widely and effectively used.
- Special effort should be directed toward improving the environment within which communications and work are occurring.

Quality Assurance Practices and Procedures

- The TOP-018 procedure should be revised to clearly establish that SRDs must be developed before any code development or modification work is initiated and to provide additional guidance on the level of detail required for SRDs.
- TOP-018 should require that SRDs be reviewed and approved by both CNWRA and client management prior to implementation, and revised, reviewed, and approved again if significant changes occur.
- The CNWRA management should reiterate the critical importance of internal reviews, and emphasize the need to stop delivery of a product if it does not meet CNWRA standards of quality and completeness.

3 BACKGROUND

Performance assessment (PA) is an analytical technique that is used within the high-level waste (HLW) program to evaluate whether the proposed repository will meet the regulatory requirements that have been established to ensure the protection of health and safety and the environment. Within the U.S. program, all interested parties have adopted some version of PA to quantitatively evaluate long-term repository performance. For the Department of Energy (DOE), PA is the basis for the "safety case" that they will make to demonstrate compliance with applicable NRC regulations and Environmental Protection Agency (EPA) standards. PA is also a central element of the DOE Viability Assessment (VA) that is scheduled to be completed in 1998. As the regulatory authority for HLW disposal, NRC will use PA to determine whether DOE has complied with the pertinent regulations. In the intervening years, PA assists NRC in identifying, assessing the relative importance of, and resolving at the staff level key technical issues (KTIs). PA also plays an important role in evaluating EPA proposals regarding an HLW standard and in developing the companion NRC implementing regulation. Utility groups [e.g., the Electric Power Research Institute (EPRI)], the State of Nevada, and other affected parties use PA techniques to independently evaluate the radiological health and safety and environmental effects of the proposed HLW repository.

Because of its central role throughout the repository program and its overarching relationship to all activities within the NRC HLW regulatory program, PA and the development of a capability to conduct PA are vitally important. Consequently, NRC began development of a PA methodology and associated computer codes about 15 years ago. Beginning in the late 1980s, NRC established a policy that NRC staff would be fully capable of conducting PAs to support precicensing and licensing activities. Subsequently, NRC staff began playing a larger role in the development and use of the PA computer codes, in particular.

The first such endeavor took the form of a project dubbed "Iterative Performance Assessment, Phase 1" (IPA-1). This effort began shortly after the CNWRA was established but before PA staff had been acquired at the CNWRA. Consequently, the preponderance of the effort was conducted by NRC staff. IPA-1 was conducted using a set of computer codes that were previously developed by Sandia National Laboratory (SNL) and other contractor organizations, or were developed by NRC staff to meet the particular needs of the effort.

IPA-2 involved the staffs of the NRC Office of Nuclear Material Safety and Safeguards (NMSS) Division of Waste Management (DWM), the NRC Office of Nuclear Regulatory Research (RES) Division of Regulatory Applications (DRA), and the CNWRA. This collaborative effort (i) produced an integrated computer code known as the Total-system Performance Assessment code, Version 2.0 (TPA Version 2.0); (ii) developed a trained NRC and CNWRA staff team capable of conducting PA analyses; and (iii) documented the results of a trial assessment of repository performance that received wide distribution.

Code development associated with IPA-3, the most recent phase of the PA program, is the subject of this lessons learned analysis. Unlike its predecessor, IPA-3 was undertaken largely using the staff and resident skills of the CNWRA. Coordination was predominantly through a single point of contact [i.e., the NRC Program Element Manager (PEM) and the CNWRA Principal Investigator (PI)] during the planning process and the early stages of code development. A brief description of the code development activities was included in the CNWRA Operations Plan. Key dates related to planning and developing IPA-3 and the associated TPA Version 3.0 code are summarized in attachment 1.

4 INVESTIGATIVE METHOD

This analysis was prepared as part of the ongoing process of evaluating, monitoring, and taking remedial actions concerning problems that arose during development and distribution of TPA Version 3.0 and its successors. To avoid duplication of efforts and in an attempt to achieve a reasonably consistent understanding of what occurred and why, this analysis drew from several sources. These included (i) the annual QA Audit 97-01, (ii) work on CAR 97-03 that was generated by that audit, (iii) the deliberations of a process improvement team (PIT) that was formed to reexamine TOP-018 "Development and Control of Scientific and Engineering Software" in light of CARs 97-02 and 97-03, (iv) the results of an independent analysis by a member of the SwRI Software Engineering Department (SED), (v) limited independent interviews of key CNWRA staff and management, (vi) consideration of the internal NRC lessons learned on this subject, and (vii) reviews of program documentation.

Wherever available, written documents were used as primary information sources concerning the facts surrounding the development and delivery of TPA Version 3.0 and its successors. Much of the information, however, was obtained from discussions with various staff members, managers, auditors, and reviewers. Relatively little information was available in written form, and much of what was written was a transcription of anecdotal information and conversations. Consequently, substantiation of information was difficult, and memories of individuals were found to differ as to what was communicated and when it was communicated relative to key decision points. The relative sparsity of written communication and documentation of agreements is believed to have played a substantial role in the problems encountered.

The reader is referred to a number of related documents for additional details regarding the plans, discussions, critiques, and associated responses. Particularly germane are (i) CNWRA Operations Plan, Revision 8, Change 0; (ii) CNWRA Operations Plan, Revision 9, various changes; (iii) Software Requirements Description (SRD), January 28, 1997; (iv) the NRC Review of the SRD, February 18, 1997; (v) Concerns Regarding CNWRA Actions in Support of the Development of the TPA 3.0 Code, February 26, 1997; (vi) the CNWRA response to this item, March 6, 1997; (vii) Non-Acceptance of Updated User's Guide for TPA Code, May 8, 1997; (viii) the CNWRA response to this item, May 22, 1997; and (ix) CNWRA Audit 97-1 Report, transmitted to NRC July 11, 1997.

5 ROOT CAUSE ANALYSIS

The investigative method outlined in section 4 was used to identify and analyze potential root causes for the problem. Three components of each root cause that was identified during the investigation stage are documented. First, observations of factual matters and perceptions of what went wrong and why are enumerated. These observations are based on interviewing staff members, inspecting pertinent project documentation, and reviewing the results of QA Audit 97-01. Second, implications with respect to product quality, timeliness, and the like are identified based on an interpretation of those observations. Because of the interrelationship between these first two items, they are discussed together in a single subsection within each root cause. Third, specific recommendations for preventing recurrence of the observed problem and/or mitigating its effects are made, as summarized in section 2.

The investigation and evaluation suggest that four root causes underlie the observed problem, although those interviewed named other more specific root causes that are treated as subsets of these four. The root causes are (i) failure to secure adequate participation of NRC staff in code development; (ii) lack of-accuracy and consistency in the planning process; (iii) inadequate communications and dissemination of information, including identifying and reporting problems; and (iv) deficiencies in quality assurance practices and procedures. Each of these root causes is discussed in the following sections.

5.1 Participation of NRC Staff in Development

It appears that the fundamental underlying problem is that CNWRA developed the TPA Version 3.0 code alone, without the benefit of NRC participation as was the case for IPA-2. Lack of NRC staff participation in code development had collateral effects on the planning process and communications, in particular, which are discussed in sections 5.2 and 5.3, respectively. The following discussion explores this root cause in its historical and programmatic context.

IPA-1 was conducted almost solely by the NRC staff, since the CNWRA had not yet staffed up in this technical area. While it was an important initial effort, the IPA-1 activity did not develop the integrated software and breadth of staff expertise that will be required for repository licensing.

In an effort to improve the effectiveness of the IPA effort, IPA-2 was undertaken as a joint collaborative effort with approximately equal numbers of staff from the NRC and CNWRA. Furthermore, a three-member management oversight board was established that comprised representatives of the NRC DWM, NRC DRA, and the CNWRA. Two team leads were selected from each of these three organizations to manage code development, testing, and operations, as well as production of a comprehensive report on the results of the work. TPA Version 2.0 was developed as part of this effort. This endeavor was widely judged to be a notable success.

Despite the success of IPA-2, the development and conduct of the IPA-3 program took a different approach. Following an extended period of planning that began shortly after IPA-2 was completed, Phase 3 code development was conducted with the CNWRA as the lead with only minor NRC staff involvement. It is noteworthy, however, that the CNWRA carried forward into Phase 3 TPA code development several lessons learned during IPA-2. These included (i) selection of an individual as PI for the TPA code modification effort who had an exceptionally high level of familiarity with TPA Version 2.0; (ii) adoption of the recommendations for code improvements noted in the IPA-2 final report, to the extent permitted by time and resources allocated to the effort; (iii) modification of the basic architecture of the code to make the code easier for a broad cross-section of NRC and CNWRA staff to use; and (iv) retention of the methodology for risk calculation in TPA Version 3.0.

For the first three months of FY97, CNWRA assumed the role of sole developer, consistent with allocated resources. As a result, the wealth of knowledge and experience developed during IPA-1 and IPA-2

were largely untapped by the CNWRA, and the broad base of support needed to modify the code and gain acceptance of TPA Version 3.0 was not developed. This approach also had the unintentional effect of excluding a number of senior staff from the process. The principal NRC participant during this time-frame was the PEM.

5.2 Accuracy and Consistency of the Planning Process

General planning for IPA-3 took place over an extended period, although essentially no code development work was done prior to FY97. The timetable for Congressional budget decisions delayed proper planning for the FY97 scope of work, including that related to TPA code development. Significantly, CNWRA operated without the benefit of a revised plan until December 27, 1996, three months after the beginning of the fiscal year and a little over one month after NRC first expressed concern regarding TPA development.

An examination of the planning process that accompanied TPA code development is enlightening. The CNWRA developed Revision 8, Change 0 of its Operations Plan for FY97 that was submitted July 26, 1996, and approved by NRC shortly thereafter. This plan called for modification of the TPA Version 2.0 code, but provided relatively little detail regarding what would be done and who would do it. The description stated that the planned activities would include (i) modifying the code to make it more representative of the YM setting and current repository design, (ii) formulating and developing improved abstractions and consequence modules, and (iii) modifying the outputs to match new regulatory requirements. While implying that a rather substantial revision of the code was planned at that time, the description did not state that a new architecture would be adopted for TPA Version 3.0. The completion date for the code modifications and user guide was established as August 29, 1997.

Following the budget cut, a complete replanning effort ensued. The former NRC PEM led this replanning effort, which included the CNWRA PI, EM, and Technical Director (TD), and involved meetings with the KTI leads. The revised Operations Plan (i) provided a much more complete description of the scope of code development, which implied an increased scope of work; (ii) redirected the overall TPA effort to focus on sensitivity analyses; (iii) maintained resources essentially unchanged relative to the July 26, 1996, Operations Plan; and (iv) accelerated the due date for completion of TPA Version 3.0 some 5-1/2 months to March 17, 1997. The description of the planned activities provided in Revision 9, Change 0 of the Operations Plan, which was issued December 30, 1996, states that "using the IPA Phase 2 version of TPA as a starting point, a new version of the code will be developed for use in the KTI sensitivity analyses." The phrase "new version" was used no less than three times in the brief one-paragraph description, seemingly leaving little doubt that a major revision was planned and, in fact, was well underway. The language in Operations Plan Revisions 8 and 9 notwithstanding, electronic mail records and recollections of agreements reached in meetings suggest a much more modest endeavor was to be undertaken. The NRC staff generally considers that the resources and schedule were appropriate for the modest changes they envisioned. This is discussed further in section 5.3.

This analysis concludes that the plan and schedule were fundamentally flawed from the outset in one or both of two ways. First, the scope of work was insufficiently defined in the operations plan to provide a clear, complete, and unambiguous determination of what was to be accomplished. Several NRC and CNWRA staff members agreed that neither a common expectation of what was required nor a uniform vision of how to fulfill that expectation was achieved. Some suggested that there was not a recognition of the extent of changes that were required to accommodate DOE revisions to the repository design and anticipated EPA revisions to the standard. Second, resources were inadequate for the scope of work that was executed. The CNWRA clearly undertook a task that was much larger than could be completed while maintaining its traditionally high quality standards. Furthermore, resources allocated to the NRC staff were insufficient for them to play a leadership role from conceptualization through evaluation of the code modifications.

The CNWRA did not obtain consensus on the scope of work, nor identify and seek to correct the perceived discrepancy among scope, schedule, and resource allocation. Three vehicles are readily available for notification of such concerns and implementation of associated changes: (i) Operations Plan modifications, although these plans tend to be general in nature; (ii) the Program Manager's Periodic Report (PMPR); and (iii) technical direction, which may be requested by the CNWRA or unilaterally provided by the NRC. None of these vehicles was effectively used to identify or address perceived inaccuracies and inconsistencies in the planning process.

5.3 Communication and Dissemination of Information

It is clear in retrospect that communications were inadequate throughout the TPA Version 3.0 planning and development phases. Most of those interviewed cited inadequate communications as the greatest contributor to the TPA code development problem. The levels, effectiveness, and, perhaps, frequency of communication were not adequate for a project of this complexity. Regular ongoing discussions were taking place, however, at the PEM/EM and PO/PI level throughout the course of planning and implementing TPA Version 3.0 code development. These discussions were expanded to include the CNWRA TD during the December 1996 to January 1997 timeframe. Early indications of differences in perspective regarding the approach to TPA code development should have been raised up the management chains within the organizations, but this was not done for a considerable time.

Correspondence from the director of DWM to the president of the CNWRA indicates that at least some at NRC believe the CNWRA has not been forthright in its communications with the NRC. An alternative perspective on the apparent lack of forthrightness that the NRC reported may be gained from considering that (i) communications among the key CNWRA and NRC staff were limited to relatively few individuals; (ii) changes in management and lead technical staff took place within both organizations during the critical time of Operations Plan modification, SRD preparation, and early TPA code development; (iii) the understanding of the CNWRA PI and EM regarding what code modifications were required continued to evolve throughout this period; and (iv) different meanings were ascribed to terms that were central to developing a clear understanding of what was and was not being done (e.g., "architecture").

Taking into consideration the information provided in the context of both of these perspectives, this lessons learned analysis was unable to determine conclusively whether information was being deliberately withheld from the NRC, or whether the apparent lack of forthrightness was simply a reflection of evolving understanding on the part of the CNWRA EM and staff. Elements of both perspectives were clearly evident in the interviews and were undoubtedly contributors to the communications problem.

An attempt was made to identify factors that contributed to the inadequacy and an apparent lack of openness in communications between the staffs. Several contributing factors were identified through the interview process. These included (i) a lack of a common vision regarding both the changes required to the TPA Version 2.0 code and the fundamental approach to be used in developing Version 3.0; (ii) a sense that there was a lack of acceptance of new and different ideas; (iii) an unwillingness to involve a broad and diverse range of staff in the process; (iv) beginning in early 1997, a tendency to rapidly elevate matters to senior management before the issue was worked at the staff or section leader level; (v) time constraints on both staff and management at the NRC and CNWRA that allowed relatively little time for thoughtful interaction, exploration of new ideas, and consideration of alternative views and approaches; and (vi) inadequate documentation of verbal agreements.

A final factor that should be considered is the overall role of the CNWRA management in the identification and communication of budding problems and solutions to such problems. The late determination of the budget, delays in the planning process, and the press of business may have resulted in a *de facto* "management by exception" approach at the CNWRA. In addition, senior CNWRA management took a position early in 1997 of lessening day-to-day involvement in TSPA activities to foster a stronger

working relationship at the EM-PEM level. Both of those actions played a role in (i) diminishing the effectiveness of communication within the CNWRA and with the NRC and (ii) allowing things to progress to where a significant problem developed before the full attention of management was brought to bear.

5.4 Quality Assurance Practices and Procedures

All scientific and engineering software that is obtained, modified, or developed by the CNWRA and is also intended to be used to conduct analyses in support of regulatory reviews is required to be under configuration control in accordance with TOP-018 "Development and Control of Scientific and Engineering Software." The controls implemented through TOP-018 include requirements for (i) a software requirements description, (ii) design and development, (iii) design verification, (iv) installation testing, (v) configuration control, (vi) software problem reporting and resolution, and (vii) software validation. The specific controls applied depend on the software category. Any particular item of software is assigned to one of three such categories: (i) developed or modified software, (ii) acquired or existing and not to be modified by the CNWRA, and (iii) acquired or existing and to be modified by the CNWRA. The development of the TPA Version 3.0 code that is the subject of this analysis falls within the first category.

Designation and transmission of "beta" versions of the code. The CNWRA transmitted variations of the TPA Version 3.0 code on March 14, April 4, and April 16, 1997, the last date being the official release date of the code. Although QA Audit 97-01 reported that these versions were transmitted without proper discrimination among versions, this does not appear to be true upon further investigation. The lead code developer has since confirmed that the code output files indicate distinct version numbers (e.g., 3.0 beta, 3.xxx, etc.). Correspondence used to transmit these early versions was not clear, however, regarding either the alphanumeric designation or state of development of the code. This led to confusion and, to at least some degree, a sense among the NRC staff that the CNWRA was misrepresenting the product that was delivered.

The QA audit also questioned whether the approach of providing a client with incomplete versions of a code was wise from a contractual perspective. The independent analysis by the SwRI SED evaluator raised similar questions, and recommended against the practice. It is the view of the CNWRA, however, that early transfers of codes are essential when the CNWRA and NRC are jointly developing a code. This approach was used successfully during IPA-2 and was also pursued in developing TPA Version 3.0, although the NRC staff was not involved until much later in the process.

CNWRA staff interviewed as part of this lessons learned indicated that evolving requirements (particularly during 1997) and late inputs from participants (some were received on the ship date) were significant contributors to the quality assurance aspect of the problem. Although considerable module testing was accomplished, testing of the integrated code was minimal. These comments have merit. In the broader context, however, the changes directed by NRC staff were required because of inadequacies in communications, insufficient definition and agreement regarding the scope of required code revisions, and significant shortcomings in the delivered code.

Review and decision to transmit code. Although each version of the TPA code was properly and uniquely identified, a key concern of the QA audit, none of the early versions of the code met NRC requirements and expectations. A proper technical and programmatic review of the code following QAP-002 "Review of CNWRA Documents, Reports, and Papers," performed against an appropriate standard of acceptability should have identified shortfalls relative to both technical adequacy and contractual requirements. A QA "stop work" on the transmittal would have prevented transmittal of the initial and, perhaps, subsequent beta versions of the code.

Early evaluations of the appropriateness for a stop work order identified two factors that suggested that a stop work order may not have been an appropriate action in this case. First, TOP-018 is not explicit

regarding distribution and use of beta versions. Second, the NRC had specifically directed transmittal of the code so that it would be available for early test and evaluation by the NRC staff. As this lessons learned evaluation progressed and additional information was developed, however, it became increasingly clear that a stop work (i.e., stop delivery) was an appropriate action to consider. Although differing staff perspectives regarding the expected state-of-development of the code transmitted March 14th persisted throughout this evaluation, written documentation clearly establishes that this milestone did not meet the contractual requirements.

Development and content of the SRD. Several problems have been identified with the SRD development process and the SRD content. Aspects of some of these problems were identified during the annual QA audit, while others were identified during this lessons learned analysis. Key points include (i) although several draft versions of the SRD were provided in late 1996, a final SRD was not transmitted until January 28, 1997; (ii) substantial work was done before the SRD was approved and approval occurred only one month before the code was delivered; (iii) a parallel approach to SRD and code development was pursued because of the stringent schedule; (iv) some saw ambiguity in the TOP-018 requirement that an SRD should be "prepared prior to significant development or modification of computer codes;" and (v) the level of detail of the SRD was insufficient to fully inform the NRC of the extensive nature of the changes to the code that were envisioned by the CNWRA.

The SwRI software quality assurance expert involved in QA Audit 97-1 made strong statements regarding the lack of recognition by the CNWRA staff that "they are members of a software development organization." In addition, he implied that an approach such as the Capability Maturity Model (CMM) of the Software Engineering Institute (SEI) could provide more timely and less expensive software development. The CNWRA management maintains that its staff develops software as tools for problem-solving and, consequently, are not software developers in the model of the SEI. Furthermore, the CMM requires particular management structures, procedures, and protocols that are markedly different from those in use at the NRC. Because joint CNWRA/NRC code development is the preferred paradigm, the suggested approach could not likely be implemented, since it would drive organizational changes at the NRC as well as at the CNWRA.

14/35

ATTACHMENT 1

Brief Chronology of Events in Planning and Developing TPA Version 3.0

- 03/94 CNWRA submitted a report on input to the IPA-3 plan.
- 11/95 Completed IPA-3 planning; plan submitted by NRC PEM for management approval prior to implementation.
- 7/96 CNWRA Operations Plan Revision 8, Change 0 submitted 7/26/96; delivery date for TPA Version 3.0 established as 8/29/97. NRC approved the plan 9/3/96.
- 10/96 Development of TPA Version 3.0 began.
- 11/96 CNWRA staff noted significant changes were being made in Phase 2 code to make it easier to use. NRC staff believed that the Phase 2 architecture was still being used and had some reservations about some of the changes.
- 12/96 CNWRA Operations Plan Revision 9, Change 0 submitted 12/30/96, incorporating significant revisions in the scope and description but not the resources allocated to TPA code development; delivery date for TPA Version 3.0 revised to 3/17/97. NRC approved the revised plan 1/31/97.
- 12/96 The NRC PEM and Project Officer (PO) were changed.
- 12/96-1/97 NRC staff expressed concern to CNWRA about not being informed of major changes to the code and noted the programmatic significance of the code.
- 1/97 In an HLW Board meeting, the CNWRA staff informed NRC that the Phase 2 architecture had been abandoned. NRC indicated that they were not aware of the decision to develop a different code architecture. CNWRA provided rationale for using a different architecture.
- 1/97 In another HLW Board meeting, senior NRC management noted that the HLW Board had agreed to use the Phase 2 architecture and that any changes to that architecture were to be brought to the Board.
- 1/97 The CNWRA formally transmitted a Software Requirements Description (SRD) to the NRC for comment (note that one or more drafts were previously provided to the NRC).
- 1/97 Partial "beta" version of code informally delivered to NRC. Major components of analysis were not included in this version (e.g., NEFTRAN).
- 2/97 NRC cautiously agreed to move forward with TPA Version 3.0 architecture rather than returning to the Phase 2 architecture. CNWRA and NRC staff were questioned by the HLW Board about whether the 3/17/97 delivery date for a code capable of doing sensitivity studies was achievable; CNWRA did not raise any objection to that date when an affirmative answer was given by NRC staff.
- 2/97 NRC staff discovered in testing the "beta" version of the code that the SNL Latin hypercube sampling (LHS) module had been replaced with a code of lesser capability.

This action had not been discussed with NRC staff and was judged to be in direct contradiction to previous agreements.

- 2/97 NRC staff accepted the TPA Version 3.0 SRD with the stipulation that the code to be delivered on 3/17/97 would be sufficient to conduct sensitivity analyses.
- 2/97 The DWM director sent a letter to the CNWRA president that noted concerns about the lack of CNWRA communication of major changes to the code. The letter specifically identified removal of the LHS module as an example.
- 3/97 The CNWRA president sent a letter to the DWM director that noted and took responsibility for problems in communication, but suggested that significant changes in management of the program may have been a contributing factor.
- 3/97 TPA Version 3.0 was received by NRC on 3/17/97. The transmittal letter noted that TPA Version 3.0 had been run and the results checked for reasonableness. It also noted the CNWRA intention to freeze the code after shakedown tests were completed. There was no indication in the transmittal that this was a "beta" version of the code.
- 3/97-4/97 NRC staff carried out an extended acceptance review of the TPA Version 3.0 code, including functionality testing. Staff found that the code (i) had major functionality problems that led to indefensible results, (ii) was not sufficiently developed to perform sensitivity studies, and (iii) had not been adequately tested and verified. NRC staff also questioned the adequacy of implementation of the QA procedure TOP-018 "Development and Control of Scientific and Engineering Software."
- 5/97 NRC staff rejected the TPA Version 3.0 code because it did not meet the requirements in the operations plan and the expectations laid out in the NRC acceptance review of the SRD.
- 5/97 CNWRA responded to non-acceptance of the code, suggesting that the 3/17/97 deliverable was a "beta test code," indicating that controls had been put in place to eliminate the root cause of problems, and agreeing to a delivery date for a functional code on 8/8/97.
- 6/97 The annual internal QA audit of the CNWRA found that TOP-018 was not effectively implemented in TPA Version 3.0 code development, and CAR 97-03 was issued.
- 7/97 NRC staff visited the CNWRA to assist in testing the revised code. A consensus developed that the code would not be ready for sensitivity studies on 8/8/97.
- 7/97 NRC staff briefed the NRC management on the status of the code and noted that it believed a functional code could be available by 9/8/97.
- 7/97 In a document titled "Actions and Agreements for Completion of Total-System Performance Assessment Code", it was agreed that CNWRA would supply a functional TPA Version 3.1 code on 9/8/97 with a limited user's manual. Full testing and verification will be completed by 3/98 to support VA review activities.

- 7-8/97 CNWRA transmitted evolving beta versions of the TPA code for testing by NRC and CNWRA staff; ongoing code verification and associated modifications were conducted under TOP-018 using Software Problem Change Requests (SPCRs) to document changes.
- 9/8/97 Delivered the TPA Version 3.1 code to NRC, together with sufficient instructions to load and execute the code.

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

18/35

RECEIVED
NUCLEAR WASTE
REGULATORY DIVISION

October 21, 1997

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Dr. Robert G. Baca
Performance Assessment Element Manager
Center for Nuclear Waste Regulatory Analyses
6220 Culebra Road, Bldg. 189
San Antonio, Texas 78238-5166

SUBJECT CODE 767-2
PROJECT NO. 20-1402-761
css (20-5705-761)

Dear Dr. Baca:

SUBJECT: ACCEPTANCE OF TPA VERSION 3.1 COMPUTER CODE (IM 5708-762-730)

On September 5, 1997, the CNWRA submitted the total system performance assessment code (TPA Version 3.1) as partial fulfillment of Intermediate Milestone (IM) 5708-762-730 (Updated User's Guide for TPA Code) which had been previously submitted and not accepted by the NRC staff. This is to inform you that we have tested and evaluated the TPA Version 3.1 code and find it acceptable to perform the process-level sensitivity studies and, therefore, consider it to be an acceptable deliverable based on the specifications in the CNWRA Operations Plan. This acceptance of the TPA Version 3.1 code is considered partial acceptance of IM 5708-762-730 because full acceptance of the IM must await submission of the User's Guide that accompanies the code. The User's Guide is now expected to be delivered to the NRC on December 12, 1997.

CNWRA staff within the Total System Performance Assessment and Integration Element are to be commended for their dedication and strenuous efforts in producing what we now believe is a code that provides NRC with considerable flexibility and significantly improves upon preexisting computational tools. Although continued testing of the TPA Version 3.1 code during the sensitivity studies could result in the identification of changes that need to be made to the code, this is considered part of the normal "debugging" associated with code verification.

I believe that the TPA Version 3.1 code reflects the excellent team effort that has taken place between NRC and CNWRA staff over the past 5 months. We should both strive to ensure that working relationships between NRC and CNWRA staff continue to improve. If you have any questions, please contact me at (301) 415-7289.

Sincerely,

Keith I. McConnell, Element Manager
Total System Performance Assessment and
Integration KTI
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

cc: W. Patrick
Director
EM
Sitakanta
Ron Janetzke

cc: J. Linehan, PMDA
B. Meehan, CMB1/ADM

MEMORANDUM

19/35

DATE: September 23, 1997

TO: W. Patrick, B. Sagar, B. Mabrito

FROM: *PCL* M. Ahola, P. Lichtner (Chairman), S. Mohanty, W. Murphy, and J. Stamatakos

SUBJECT: TOP-018 Revision Committee Recommendations

*meeting held 10/14/97
with W. Patrick, B. Sagar,
B. Mabrito, P. Lichtner
to discuss this memo
and determine "next
steps" to*

Consensus was reached regarding recommended changes to TOP-018, Development and Control of Scientific and Engineering Software. These recommended changes are based on the results of the CNWRA internal audit described in Audit Report 97-1. Specifically, the audit report recommended that a team comprised of code developers and users should be established to better define TOP-018 requirements. The committee also took into consideration the contents of the letter to H. Garcia from S. Fortuna dated July 8, 1997 on the subject: Approval of CNWRA TOP-018, Revision 5. In this letter Ms. Fortuna recommended that the technical staff should assume "ownership" of TOP-018 to ensure effective implementation of the procedure. The recommended changes to TOP-018 follow the comments offered by S. Dellenback regarding Division 20 software development procedures in his memo dated August 10, 1997 to W. Patrick and R. Curtin.

*change TOP-018
P. Lichtner and
Process
Improvement
Team will
take action
on TOP-018.
SEN
10/14/97*

Dellenback emphasized the need for a Software Development Plan (SDP) in addition to the Software Requirements Description (SRD) already required by TOP-018. In addition, he noted the need for an Acceptance Test Plan (ATP) not currently called for in TOP-018. The purpose of the ATP is to demonstrate to the client that the code development outlined in the SRD and SOW has in fact been fulfilled.

Dellenback raised 5 specific issues:

- (i) Tailored software development procedures need to be identified for each software development project in a project-specific SDP.
- (ii) Software requirements must be more thoroughly documented in the SRD and formally reviewed with the customer.
- (iii) More documented testing needs to occur which should be formally documented in an ATP.
- (iv) Quality of source code is inconsistent and does not adhere to generally accepted software engineering practices.
- (v) Non-Computer Science trained staff are developing and delivering software.

Each of these items was addressed by the committee. The committee's recommendations are discussed below.

- (i) The committee agreed that preparation of a SDP should be included in TOP-018. Dellenback noted that:

It is very difficult to write a single set of software development procedures with any substance that can logically apply to all software development projects. Each software project needs to tailor TOP-018 to best fit the requirements of the program.

The committee felt that this was especially true of the CNWRA where a great variety of codes are being developed (TPA, MULTIFLO, 3DSTRESS, ...) or modified (VTOUGH/CTOUGH, EQ3/6, ...). Each code has a different purpose and different level of visibility with clients. The TPA code has input from many individuals both at the CNWRA and the NRC and a multitude of users. As such it requires special considerations to document changes in the code and to coordinate new releases to the users. MULTIFLO currently is being developed by two individuals, P. Lichtner and a consultant (M. Seth) and does not have the same level of visibility as does the TPA code. However, MULTIFLO is also being marketed in WFO and may have other requirements.

TOP-018 would be altered to provide general guidelines for developing a SDP. The SDP would provide an interface to TOP-018 for each code being developed or alteration of an existing code. The purpose of the SDP is to interpret how TOP-018 will be applied to a particular code. Future audits would need only refer to the relevant SDP, rather than TOP-018 itself. Each code developer would need approval from his/her element manager, QA, and the software development board to implement the SDP. The SDP appeared to be the most flexible approach to meet the needs of the CNWRA, where codes with widely varying requirements are being developed. The SDP would detail specifically for each code being developed at the CNWRA:

- style guideline
- configuration management
- code baselining
- changes to baseline
- change requests
- issuance of new releases
- Acceptance Test Plan (ATP)

Those parts of TOP-018 that refer to detailed requirements, such as preparation of an SPCR form, would be deleted as this function would be provided by the SDP tailored to each code's particular needs. Other suggestions made by Dellenback, such as the ATP, would be optional and would also be detailed in the SDP, rather than in TOP-018. Other recommendations were to include Cook et al. as an appendix to TOP-018 so that a copy is easy for the developer to locate.

(ii) The committee agreed that the SRD requirement as currently implemented in TOP-018 was adequate, but that the length of the SRD should not be restricted arbitrarily, but decided by the developer and project manager. In addition the committee agreed that the SRD should become an intermediate milestone and reviewed by the client (NRC) for appropriateness and buyoff.

(iii) In its present form TOP-018 does not call for an ATP document. Testing of code is documented in the developers scientific notebook. The committee felt that a formal ATP could be useful in certain instances to demonstrate to the client that what was stated in the SRD was actually carried out.

(iv) The committee agreed that style guidelines should be spelled out in the SDP and adhered to during code development and subsequent modifications. The tendency has been to consider code

"good enough" if it works. However, a recurring issue at the CNWRA has been code reusability and clean code could certainly help in this regard. As noted by Dellenback (private communication to P. Lichtner), however, writing "good" FORTRAN code seems to be a virtually impossible task. Object oriented programming languages have been specifically developed to deal with the issue of code reusability, but such languages in their present state of development may not be appropriate for number crunching codes such as MULTIFLO.

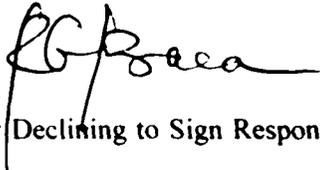
(v) The committee felt that this item was a management decision and fell outside the scope of TOP-018. It was agreed that CNWRA staff are primarily concerned with producing results useful for analyzing specific problems such as disposal of nuclear waste at Yucca Mountain. Codes are generally viewed as a means to an end and not an end in itself. Considerations of budget and time must be addressed as well because hiring a professional software developer would be expected to greatly increase the cost of software development and could prolong the time to complete coding.

The committee's next step, if management gives approval for the direction outlined in this memo, would be to modify TOP-018 in accordance with the suggested changes presented above. Much of TOP-018 can be left intact. Sections 5.4 Design and Development, 5.5 Design Verification, 5.6 Installation Testing, 5.7 Configuration Control, 5.8 Software Problem Reporting and Resolution, and 5.9 Software Validation, would be modified and/or replaced by guidelines for producing the SDP including optional development of an ATP. The SPCR form would be eliminated and replaced by guidelines for implementing change control as detailed in the SDP. The committee feels that implementing the plan to improve TOP-018 as outlined in this memo would provide a flexible approach to computer code management and would improve the quality of software developed at the CNWRA.

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES**MEMORANDUM**

August 13, 1997

To: QA File

From: R.G. Baca 

Subject: Reasons for Declining to Sign Response to CAR 97-03

Reference: Memo from Dr. W.C. Patrick to the QA file, date August 4, 1997

The letter of Dr. W.C. Patrick to the QA File (Reference) incorrectly states the reasons I gave for declining to sign the response prepared by Dr. B. Sagar and finalized by Dr. Patrick for the subject CAR. I did not sign the response for two basic reasons. This memo is intended to formally document those reasons and thereby correct the QA record.

First, neither I as EM or the PI, S. Mohanty, were permitted to make any contributions or revisions to the response authored by Drs. Sagar and Patrick. To have this document written solely by upper management rather than those directly involved in the work, in combination with the expectation that I sign it without providing my own views, I felt was unreasonable.

Second, there were three very significant points absent in the version presented to me:

- (i) the fact that the change in the NRC PEM for the TSPA1 KTI had a significant impact on the continuity of the work scope agreed to with the former PI, R. Manteufel and myself.
- (ii) the fact that the short time schedule permitted for the development of the TPA code had a deleterious impact on the quality of the final code delivered to NRC.
- (iii) the fact new NRC PEM and his management knew that very limited testing of the TPA 3 code would be performed prior its release, and therefore NRC understood it was a beta version.

With regards to item (i), in mid-November 1996 the NRC PEM Rex Wescott transferred to a different group and was replaced by Tim McCartin. Mr. McCartin had a distinct approach in terms of interfacing with the Center staff and, more importantly, had a distinct vision for the code than Rex Wescott. Prior to preparation of this response to the CAR, Dr. Sagar had noted this fact as a significant factor. The omission of this important point, I believe was because of simple oversight. If I had been given the option to contribute, I would have added this fact.

Concerning item (ii), the NRC letter to Dr. Patrick concerning the rejection of the TPA 3 code clearly acknowledges the imposed time schedule, yet the response to the CAR makes no mention of the time constraints on this activity or its impact on the final product. To my recollection, Dr. Patrick made it very clear to NRC in a Branch Chiefs meeting that the Center staff was "parallel processing" between developing code, testing individual modules, conducting meetings to formulate modules, and preparing

Memo to:
QA File, Page 2
August 13, 1997

documentation in order to meet the deadline. Also, I would note for the record that according to the NRC staff, it took one year (with a number of schedule slips) to develop the TPA 2 code and it received about 6 months of testing. Contrast this with the TPA 3 code which the PA Element staff devoted about 5 months of development and about one and half weeks of testing the whole code. Furthermore, the comments of the Audit Team supports the fact that too little time was available for completion of such a large and complex code development activity. Moreover, because of the Audit Team comments, the Center is currently being advised by S. Crumrine (Div. 10) and her staff on how to improve the control of software development activities. Again, if I had been given the option to contribute, I would have added this fact. This omission was probably due to haste to complete and issue the response to the CAR.

On item (iii), the fact that NRC was knowledgeable about the preliminary status of the TPA 3 code is evidenced in a briefing chart prepared by Tim McCartin for his presentation to the HLW Board. This fact was noted in the response to CAR prepared by myself and the PI and a copy of the chart was attached. This was considered to be a very important point by the PI and I supported his view. However, it could have been omitted at the discretion of upper management.

I wish to note for the record that as I indicated to Mr. Bruce Mabrito, Director of QA, I felt there are many excellent points made in the version of the response prepared by Drs. Sagar and Patrick, which I am in full agreement. Also, I acknowledge that the response prepared by myself and S. Mohanty was overly brief, missed important points, and could have been improved by collaborating with Dr. Sagar. Consequently, I have requested that the response signed by me should be withdrawn from the QA file. Finally, it was not our intention to be unresponsive, rather, the press of other high priority activities competed for time to respond to CAR 97-03, namely completion of the TPA 3.1 code.

cc: W. Patrick
B. Sagar
B. Mabrito
S. Mohanty

August 10, 1997

MEMORANDUM

TO: Wes Patrick
Rich Curtin

FROM: Steve Dellenback *SWD*

SUBJECT: Division 20 Software Development

I have had the opportunity to discuss Division 20 software development procedures with various personnel within Division 20. Additionally, I have been provided a variety of documents and source code to review. My primary contacts have been Peter Lichtner and Sitakanta Mohanty.

A summary of my insights would include:

- **Software Development Procedures:** Division 20 utilizes a document entitled "Development and Control of Scientific and Engineering Software" (aka TOP-018). This document provides an overview of how software should be developed within the Center. While this document presents some good concepts, the concepts need to be applied in a different fashion to different programs (i.e. the document is not a "cure all" for all projects). It is very difficult to write a single set of software development procedures with any substance that can logically apply to all software development projects. Each software project needs to tailor TOP-018 to best fit the requirements of the program.

By contrast, the Software Engineering Department (SED) has a set of software development procedures that is currently several hundred pages long. These procedures are based on the Software Engineering Institute's (SEI) Capability Maturity Model (CMM). The goal of these procedures is to provide "development guidelines" and "best practices" which can be tailored to individual project requirements. The practice of having a set of software development procedures at an organizational level, which is tailored to specific project needs, is common in the industry today. The software development procedures are typically tailored via two mechanisms, tailoring guidelines (which are normally part of the procedures themselves) and a project specific Software Development Plan (SDP). Tailoring guidelines describe what must be done as well as what may be modified with suggestions as to "why" the tailoring might occur. It is controlled adaptation based on specific project needs and constraints. The

SDP details which parts of the software development procedures will be utilized and how they will be used.

One of the major issues that were identified during my review/discussions is that there was no consensus as to how "change control" should be implemented. While change needs to be carefully controlled to minimize "requirements creep" (which can impact cost and schedule), it is important to have a "change control" process that does not overwhelm the project. Generally accepted software engineering practices implement formal (i.e. written forms) "change control" once a product is delivered to the customer (termed the "baseline"). If modifications need to be made to the baseline, formal "engineering change request (ECR)" forms must be generated to document and track the changes. The number of changes that can be incorporated into a single ECR varies based on the development program requirements (the change control process is detailed in the SDP).

Issue: Specific software development procedures need to be identified for each software development project in a project specific SDP. This document needs to describe responsibility guidelines and provide significant detail on rules, practices, and conventions that will be applied on the project. This document should also describe how "change control" will be implemented.

Recommendation: Develop "tailoring" guidelines to accompany TOP-018 to specifically "customize" each software development effort. For significant development efforts, consider developing a document similar to a SDP; for small development efforts or software maintenance efforts, a "blanket tailoring guideline" should be developed.

Change control needs to be better defined. Because Division 20 has a variety of software development programs (in the sense that development activities widely vary), there needs to be more than one way to handle change control. The selected method for each project needs to be completely documented in the project SDP.

- **Software Requirements Document:** From a SwRI software development perspective, I believe the most important document that we produce is the Software Requirements Document (SRD). Although design documentation is important, from a contractual relationship with our customers, the SRD is the "defining" document for what SwRI is to perform. According to the software engineering literature, the most prominent cause of problems during software development projects is "mis-set" expectations, that is, the customer expects one product and the developer provides another. The SRD is a mechanism, which can formalize "what", the software is to do. In SED, we develop a significant amount of the contents of the SRD during the proposal stage (we have to in order to determine project costs). I realize Division 20 has a relatively unique contracting relationship but more effort needs to be spent on requirements.

Once the SRD is complete (this document could vary in size from very short for a simple project, to quite lengthy for a large, complex project), the contents of the SRD

need to be formally reviewed with the customer. Written customer feedback and/or concurrence with the SRD should be received from the customer. Once the SRD is approved, any requested changes must be formally submitted and considered for cost and schedule impacts. Note that even a well-written SRD will have "gray areas". There are always TBDs. Requirements may not be fully known until the project is complete. The software process needs to flag and monitor these TBDs to assure that the development is a controlled effort and not a chaotic effort. Processing of TBDs and change requests should be done in written correspondence (we use e-mail for this in many cases).

It should be noted that a complete and well-written SRD does not assure that no "issues" will arise with the customer. It does provide a "framework of expectations" which is important to be documented in the event that one of the project principles (either the customer or SwRI key team members) leaves the project.

Issue: Software requirements must be more thoroughly documented and formally reviewed with customer.

Recommendation: Initiate the development of a "classical" Software Requirements Document (SRD) whose "length" is not arbitrarily limited. Once the customer accepts the SRD, any change in requirements must be formally tracked using a well-documented procedure.

- **Testing:** At the heart of almost all "software problems" is a lack of testing. There are many reasons for this lack of testing, the most common is the lack of time. Software Engineering journals suggest that approximately 30% of the software development time should be spent "writing code". The balance of the time is in requirements, design, documentation and testing. Quality testing starts at well-defined requirements (see SRD above). In order to test, you have to fully understand what you are testing for. While "ad hoc" testing will identify problems, it should not be considered formal testing. Three levels of testing should occur on ANY software delivered to a customer:
 - **Unit Testing:** Testing performed by the developer at the "module" level to thoroughly exercise the "structure" of the code and to assure that individual subroutines/functions generate expected results. The unit tests themselves, as well as the results of the unit testing should be informally documented (hand written tests/results are acceptable).
 - **Integration Testing:** Combining "modules" to assure that an operational system has been put together. Integration test cases, as well as the results of the integration testing should be documented (the level of documentation depends on the complexity of the system being developed).
 - **Acceptance Testing:** The process of getting the customer's concurrence that the requirements (detailed in the SRD) have been successfully implemented. The

Acceptance Test Plan (ATP) needs to be a formal document that the customer reviews and approves prior to acceptance testing being initiated. The ATP should ONLY include tests to demonstrate that the requirements (detailed in the SRD) have been implemented. Failures during acceptance testing should be formally documented and corrective action needs to be detailed. At the conclusion of the acceptance test, the customer should "buy-off" the system.

Issue: More documented testing needs to occur.

Recommendation: Develop formal ATP procedures for ANY software to be delivered to a customer.

Software Implementation: It is my observation that the Institute's technical Divisions closely review reports/letters that are sent to our clients. We assure that these reports/letters adhere to standards that the Division has established. I spent time reviewing the software that has been produced; while some of the code was well documented and meets generally accepted software engineering practices, a vast majority of the code (over 75%) needs significant modification to make the source code "consistent" and "maintainable". I was not reviewing the code to see "if it works", rather I was reviewing the "style" of the code and trying to assess the "maintainability" (by either SwRI staff or the client's staff). While the "science" behind the software developed by Division 20 is complex, the style of implementation makes the code very difficult for anyone other than the author to modify. If we are delivering source code to a customer, software standards must be established and we must assure that software developed meets the same high standards we have established for SwRI generated reports/letters.

Issue: Quality of source code is inconsistent and does not adhere to generally accepted software engineering practices.

Recommendation: A "software style guideline" should be developed and all software delivered to the client should be reviewed by an independent reviewer to assure compliance with the style guideline. TOP-018 does reference guidelines but each project needs to select a style project specific guideline and adherence to the guideline should be independently evaluated.

- Computer Science Trained Staff: I realize that this is a sensitive issue but SwRI needs to assure that we are delivering quality software products. I realize that much of the software that is developed in Division 20 is done by scientists who understand the underlying problems they are trying to implement and trying to convey this information to a "programmer" would not be a feasible solution. There needs to be a "line" established in which there is a distinction made between software that is developed as a "tool" (and used internally to solve problems) and software that is a "product" (that is used by the client on a repetitive basis to solve problems).

I believe that a clear distinction can be drawn between the two types of software. There are many people who can "program" but the art of developing and delivering production quality source code is not a simple matter. If software is being used by SwRI employees to produce results that SwRI personnel are interpreting, we can be more lenient on the quality of the code (because anomalies in the code should be caught internally). However, in the cases where we are delivering code for customer execution (and validation of significant events), we should probably utilize more "formally trained" software professionals to assure that the software meets expected Institute quality standards. Another case that should be considered is the case of software that produces data that will be delivered, as a product, to a customer. In this case, software quality is also a significant issue since the customer may be making critical decisions based upon the data SwRI delivers, and the customer will expect that the data to be accurate.

As an analogy, if I need to connect two SwRI computers together, I might make my own cable (which will be functional but not "pretty"). If I am to deliver the cable to a customer, I will either purchase a commercially made cable or I will utilize a SwRI technician (who is trained in cable making) to make the cable. The Division 20 staff is clearly highly skilled in their technologies but Computer Science is a lot more than "programming".

Issue: Non-Computer Science trained staff are developing and delivering software.

Recommendation: Consider utilizing more Computer Science trained staff in the software development process or at least consider having a Computer Science trained staff member on the weekly/monthly review of all software development projects. Note that several members of the QA Department are trained in both Computer Science and QA so a single person may be able to fill several roles. If Computer Science personnel are not used on a full-time basis; consideration should be given to establishing a structured code walk-through process (using trained software staff). This would provide independent insight into the software being developed and would more than likely greatly improve the delivered product.

Corrective action to improve the above areas will not be easily performed in several weeks; however, I do believe more rigorous testing could be accomplished before the August delivery of source code to the NRC. I hope that my insights prove to be helpful. If anyone within Division 20 wishes to further discuss my comments, please have them call me at the SwRI TransGuide offices at 737-2983.

cc: Susan B. Crumrine
Peter Lichtner
Sitakanta Mohanty

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES ^{29/35}

MEMORANDUM

August 4, 1997

TO: QA File
FROM: W.C. Patrick 
SUBJECT: Responsibility for Corrective Action Request 97-03

The purpose of this memorandum is to reassign the responsibility for Corrective Action Request (CAR) 97-03 from the cognizant Element Manager, Dr. Robert Baca, to the Technical Director, Dr. Budhi Sagar. This action is being taken in an effort to assure timely and appropriate response to the subject CAR, which arose from Quality Assurance Audit 97-01 of the Center for Nuclear Waste Regulatory Analyses (CNWRA).

To date, two responses to CAR 97-03 have been prepared by Dr. Baca. The response provided on July 11, 1997, was rejected and additional instructions were provided by Mr. Bruce Mabrito and Dr. Budhi Sagar via electronic mail regarding the required contents of CARs. These instructions were concurred in by me. A second response was prepared on July 31, 1997. Upon review of this response by Mr. Mabrito, Dr. Sagar, and me, it too was rejected.

To be effective in correcting conditions adverse to quality, responses to CARs must clearly, completely, and objectively describe (i) the conditions that existed which caused or contributed to the condition adverse to quality; (ii) the root causes for those conditions, as best they can be determined; and the (iii) means proposed to avoid recurrence of the problem and mitigate the impact of the current problem. The two responses produced to date by Dr. Baca do not meet this test. In an effort to provide a more complete and effective response, Dr. Sagar drafted revised language which addresses the four key points raised in CAR 97-03. Feedback provided by Mr. Mabrito indicates that Dr. Baca does not agree with this revised language and does not intend to sign the CAR if it contains this more complete assessment. A particular area of disagreement is with regard to CNWRA responsibility for the conditions adverse to quality.

In light of the above and recent electronic mail correspondence from NRC management which indicates that NRC does not believe that cognizant CNWRA management understands the gravity of the problem and has identified the root cause of the TPA code development problem, it is my judgment that Dr. Baca cannot or will not be effective in addressing CAR 97-03. Consequently, I am assigning responsibility for addressing CAR 97-03 to Dr. Sagar, effective immediately.

cc: R. Baca
B. Mabrito
B. Sagar

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CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES 30/35

CORRECTIVE ACTION REQUEST

CAR No: 97-003

Associated AR, SR, NCR No: _____

PART A: DESCRIPTION OF CONDITION ADVERSE TO QUALITY

Contrary to the requirements of TOP-018, paragraph 5.7, two versions of the TPA code, Version 3.0, were delivered to the NRC on two different days prior to the official release date (4/16/97) which indicated completion of all requirements. In addition, the Software Requirements Description (SRD) was not prepared prior to significant development or modification of the codes as required by paragraph 5.3.1. This code has been rejected by the NRC as not meeting commitments made in the CNWRA HLW Operations Plans. The TPA code was not clearly identified as a Beta version and use of the code by the NRC for informal analyses could present problems in traceability and configuration control.

Initiated by:

Date

PART B: PROPOSED ACTION

Responsible EM: R. G. Baca

Response Due:

1) Extent of Condition:

Although individual components of the TPA Version 3.0 code were extensively tested, the complete code was not adequately tested due to the tight schedule set for this deliverable. Joint testing of the new code conducted by the CNWRA and NRC determined that some components of the TPA code were not fully functional, indicating that the code, officially transmitted on 3/17/97 to the NRC, should have been designated as a "beta" version. A second and corrected version of the beta code was provided to NRC on 4/16/97 (memo from S. Mohanty to T. McCartin), at their request, for use in further joint testing of the new code; the corrected beta code was designated as TPA Version 3.xxx; the QA auditors incorrectly "assumed" that this corrected code was issued as a second and non-distinct TPA Version 3.0.

The CAR incorrectly states that SRD was not prepared prior to significant development or modification of the code. Several versions of the SRD were prepared and submitted to the NRC for their review, comment, and approval; a half day meeting was held on 11/96 with T. McCartin, N. Eisenberg, R. Codell (telecon), and R. Wescott (telecon) to discuss the SRD; a number of months were required to secure NRC approval of the SRD; formal acceptance of the SRD by NRC was not received until 2/24/97 (code due date was 3/17/97). However, it is true that the SRD was not "finalized," i.e., submitted to the Software Review Board, prior to major code development. The SRD had been reviewed and approved by the EM by mid-December, i.e., prior to significant development of the TPA code modules.

2) Root Cause:

The problems that arose with the TPA code were largely due to underestimating: (i) the time requirement to interact with the KTI teams and establish consensus on module formulations and approaches (that were ultimately implemented in the TPA code) and (ii) the amount of testing needed to ensure that the TPA code was ready for its intended purpose. The first aspect resulted in evolving requirements that needed to be addressed within a fixed and very tight time schedule. The second item was problematic because it is impossible to know a priori how much testing would be required to debug such a large and complex computer code. Because the NRC staff and management were aware (see attached briefing chart prepared by T. McCartin for presentation to HLW Board) that the code to be delivered on 3/17/97 would have undergone "minimal" testing and debugging, the version of the TPA code delivered to NRC should have been designated as Version 3.0 β .

Regarding implementation of TOP-018, the requirements for SRD preparation and approval are ambiguous. For example, the TOP states "An SRD is the basis for software development and shall be prepared prior to significant development or modification of computer codes." The implication is that code development or modification can indeed be initiated in advance of the SRD being written and approved.

3) Remedial Action:

Proposed Completion Date: N/A

Although there were many lessons learned from this activity, the main point is that early feedback must be given to NRC upper management of unreasonable time schedules and/or tasks that are inherently difficult to estimate, in terms of time and effort required. In addition, computer codes which are in the early development stages and have not been extensively tested will be designated as "beta" versions.

4) Corrective Action to Preclude Recurrence:

Proposed Completion Date: 8/30/97

The TOP-018 procedure should be revised to clearly state that the SRD shall be reviewed and approved by the CNWRA EM and NRC PEM prior to initiating development of a new code. In addition, all KTI-level interactions required for code development must be completed and documented before the SRD is submitted to the NRC for final approval. Similarly, in the case of a major modification (i.e., to extend the functionality) of an existing code, an SRD should be prepared and approved by the CNWRA EM in advance of initiating the work, which must be in concert with the scope in the HLW OPS.

Element Manager:

Date:

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

31/35

CORRECTIVE ACTION REQUEST

CAR No: 97-003

Associated AR, SR, NCR No: _____

PART C: APPROVAL
Comments/Instructions

Director of QA:

Date:

PART D: VERIFICATION OF CORRECTIVE ACTION IMPLEMENTATION

Distribution:

Verified by:

Date:

*This response from R. BACA
WAS NOT ACCEPTED BY CNWRA QA.
Sumit Mahanta*

32/35

EXECUTIVE DECISION

Required for Either New Phase 3 or Modified Phase 2

- Individual dose for critical group
- Stylized calculation for human intrusion (Phase 2 could provide a starting point)
- Variable compliance period
- Upgrading of modules
 - significant for some such as: VOLCANO and EBSPAC
 - key changes for some aspects such as: infiltration and water well pumping

Attributes of Phase 2 that Should Remain Unchanged

- Approach for scenarios and CCDF construction
- Parameter sampling approach

PROS AND CONS FOR A MODIFIED PHASE 2 EXECUTIVE

- + Significant experience in interpreting results
- + Significant effort already spent in Debugging
- + Significant documentation available
- Data transfer between modules is cumbersome
- Center experience found code difficult to modify for TSPA 95 review (user friendliness for non-developers questioned)
- /+ Center staff believe limited flexibility exists in Phase 2 code for incorporating changes
NRC staff believe that limited flexibility due to some hard-wired parameters not a large stumbling block
- Some hard-wired parameters
- RIP did spreadsheet type of calculation. Phase III does process model calculations.

- Cannot use climate model by 3/17 although identified in the SRD.
- John - St. vs. Underly infiltration - what's the decision as will the rationale from the special committee be documented?
- One mtg - 1 issue; if cannot reach consensus elevate to the next higher level. (without 2 mks, should be in an agenda)
- Each module should jot down what are the known conservations and why
- Tim - PA needs to take a lead to identify conservations (Tim, Glennie, & Bob)

PROS AND CONS FOR A NEW PHASE 3 EXECUTIVE

- + Improved/simplified data transfer structure
- + Hopeful that past experience can be used to improve modularity and user friendliness
- + Center staff believe that required changes are more efficiently implemented in a significantly revised executive
- +/- Center staff believe in more flexibility in input structure to account for future changes
NRC staff not convinced that flexibility needed in all areas
- Extremely limited experience with interpreting results by 3/17
- Extremely limited effort for debugging prior to 3/17

RECOMMENDATION

- A new Phase 3 executive should be continued that retains key aspects of the Phase 2 approach (e.g., scenario and sampling approaches)
 - significant improvements to user friendliness anticipated which benefit current use and for future enhancements
 - major changes diminish the relevance of experience with and debugging of Phase 2

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

34/35

MEMORANDUM

July 18, 1997

TO: Corrective Action Request (CAR) No. 97-03 Folder

FROM: Bruce Mabrito, CNWRA Director of Quality Assurance 

SUBJECT: Response to CAR No. 97-03

REFERENCE: CNWRA QA Audit 97-1 and QA Procedure-010, Corrective Action

On July 11, 1997 R.G. Baca responded to Corrective Action Request No. 97-03 and returned the CAR form to CNWRA Quality Assurance signed and dated. This was within the 20 working day time frame required by QAP-010. It was noted that one section of the CAR form, "Corrective Action to Preclude Recurrence" was not completed. Initially there was a meeting between R.G. Baca and B. Mabrito to determine an acceptable response to that section, followed on July 17, 1997 by another meeting with the following attendees: W. Patrick, B. Sagar, R.G. Baca, S. Mohanty, and B. Mabrito. At the second meeting it was determined that a more complete response would be forthcoming.

On July 18, 1997, during a CNWRA Management Staff Meeting it was decided that CAR form No. 97-03 would be fully completed and returned to CNWRA QA by August 1, 1997.

In addition, in a related action, W. Patrick issued a Draft Annotated Outline for TPA Lessons Learned Analysis on July 17, 1997 with a request for comments by July 25, 1997. In that memorandum, he stated that "It is anticipated that extracts from the subject analysis can and will be used in addressing Correction Action Request 97-02, thus avoiding duplication of effort in completing these two actions." Since both CARs from the 1997 CNWRA QA Audit dealt with Software Quality Assurance and related actions, both CARs 97-02 and 97-03 may benefit from this lessons learned analysis.

This memorandum will be filed with CAR 97-03 to provide an traceable "bridge" as the CAR form is completed and will lead to effective corrective action.

cc: W. Patrick
B. Sagar
R.G. Baca
S. Mohanty
B. Mabrito

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

35/35

CORRECTIVE ACTION REQUEST

CAR No: 97-003

Associated AR, SR, NCR No:

PART A: DESCRIPTION OF CONDITION ADVERSE TO QUALITY

Contrary to the requirements of TOP-018, paragraph 5.7, two versions of the TPA code, Version 3.0, were delivered to the NRC on two different days prior to the official release date (4/16/97) which indicated completion of all requirements. In addition, the Software Requirements Description (SRD) was not prepared prior to significant development or modification of the codes as required by paragraph 5.3.1. This code has been rejected by the NRC as not meeting commitments made in the CNWRA HLW Operations Plans. The TPA code was not clearly identified as a Beta version and use of the code by the NRC for informal analyses could present problems in traceability and configuration control.

Initiated by:

Date

PART B: PROPOSED ACTION

Responsible EM: R. G. Baca

Response Due:

1) Extent of Condition:

Although individual components of the TPA Version 3.0 code were extensively tested, the complete code was not adequately tested due to the tight schedule set for this deliverable. Joint testing of the new code conducted by the CNWRA and NRC determined that some components of the TPA code were not fully functional, indicating that the code, officially transmitted on 3/17/97 to the NRC, should have been designated as a "beta" version. A second and corrected version of the beta code was provided to NRC, at their request, for use in further testing of the new code; the corrected beta code was designated as TPA Version 3.xxx. The CAR incorrectly states that SRD was not prepared prior to significant development or modification of the codes. Several versions of the SRD were prepared and submitted to the NRC for their review, comment, and approval; a half day meeting was held on 11/96 with the NRC to discuss the SRD; a number of months were required to secure NRC approval of the SRD; formal acceptance of the SRD by NRC was not received until 2/24/97 (code due date was 3/17/97). However, it is true that the SRD was not "finalized," i.e., submitted to the Software Review Board, prior to major code development.

2) Root Cause:

The problems that arose with the TPA code were largely due to underestimating: (i) the time requirement to interact with the KTI teams and establish consensus on module formulations and approaches (that were ultimately implemented in the TPA code) and (ii) the amount of testing needed to ensure that the TPA code was ready for its intended purpose. The first aspect resulted in evolving requirements that needed to be addressed within a fixed and very tight time schedule. The second item was problematic because it is impossible to know a priori how much testing would be required to debug such a large and complex computer code.

3) Remedial Action:

Proposed Completion Date: N/A

No remedial action necessary. Although there were many lessons learned from this activity, the main point is that early feedback must be given to NRC of unreasonable time schedules and/or tasks that are inherently difficult to estimate, in terms of time and effort required.

4) Corrective Action to Preclude Recurrence:

Proposed Completion Date: 8/30/97

Element Manager:

Date:

RG Baca

PART C: APPROVAL
Comments/Instructions

Director of QA:

Date:

PART D: VERIFICATION OF CORRECTIVE ACTION IMPLEMENTATION

Distribution:

Verified by:

Date:

*This response from R. Baca was
not accepted by CNWRA QA.*

Daniel Malin