PMI Award for Project Excellence Application: ***Sludge Treatment - Engineered Container Retrieval and Transport System (ECRTS) Technology Development and Readiness Project***

1. Introduction/Summary

Figure 1. K Basin Proximity to the Columbia River

Overview. CH2M HILL Plateau Remediation Company (CHPRC) is pleased to submit the Engineered Container Retrieval and Transport System (ECRTS) Technology Development and Readiness Project for consideration by the Project Management Institute (PMI) as 2016 Project of the Year. There are several major projects within the Sludge Treatment Project (STP), including ECRTS. STP's mission is to remove some of the most hazardous radioactive material on the Hanford Site away from the Columbia River. Currently, the material is stored in steel containers underwater in the 105 K West Reactor Basin only 400 yards from the Columbia River (Figure 1). Sludge is a dense, radioactive material that resulted from the corrosion of spent nuclear fuel stored in the basin and other debris left from plutonium production operations over 30 years ago. When the ECRTS stage began in 2016, its purpose was to perform final validation of technology to be used in the retrieval and transport of highly radioactive sludge in the 105 K West Reactor Basin. The final phase of the STP will commence in 2018 when workers start and complete sludge removal from the 105 K West Basin.

Organizational need. Approximately 35 cubic yards (27 cubic meters) of the sludge remain stored under 17 feet (5 meters) of water in the concrete 105 K West Reactor Basin. The sludge must be removed before the basin, now past its design life, can be demolished. This activity will help to clean the contaminated soil beneath the basin to protect the Columbia River and enable decommissioning and interim safe storage of the K West Reactor. The sludge will be removed from containers in the basin and transferred to the 100K West Annex to be repackaged. Workers will transport the material to Hanford's T Plant located at the center of the site for interim safe storage.

The ECRTS project was devised to resolve the daunting technical challenge of removing high density sludge. Using a highly disciplined, methodical engineering approach has helped with creating the technology and process to remove the radioactive material. ECRTS is based on sound theoretical foundation that uses a unique combination of fundamental engineering and state-of-the-art technology. Realizing that the application of theory to designs is only an approximation of actual performance, project management incorporated a robust test strategy in a full-scale mockup to ensure the unique design would perform as designed once installed and operational. The testing phase of the ECRTS project proved an instrumental tool that helped to confirm the performance of critical design technologies more accurately, thus reducing overall project risk.

Solution. Because sludge removal has never been performed on the Hanford Site, CHPRC re-purposed its Maintenance and Storage Facility (MASF) to conduct testing to confirm that the unique ECRTS sludge retrieval and transport system worked as designed. Workers constructed a feature-specific replica of the sludge storage basin and underwater sludge storage containers. The actual production equipment was installed in the mockup and tested at the MASF, which has played a significant role in moving the project forward safely, efficiently and compliantly. The technology demonstration was instrumental achieving removal of sludge in 105 K West Basin an estimated year ahead of schedule.

As part of the ECRTS project, CHPRC engineers and technicians used innovative technology to develop tools and modify equipment that will be used for sludge removal. The operators who will be working with the equipment once the sludge removal process begins will have the opportunity to train in the facility, use the tools and give feedback to the engineers. The procurement of tools and equipment at this facility helped save time and money. The partnership between the operators and engineers helped reduce overall project technical risk, yielding a reduction in potential issues once the actual work begins.

Figure 2. MASF Simulated K Basin Mockup

The MASF also helped to reduce the exposure to the worker. The simulated 105 K West Basin allowed workers to master the retrieval tools and processes in a safe environment free from radioactive material.

Outcomes.

2. Sponsor Letter (Will be sent later this week)

3. Benefits/Value

Value to the organization. The ECRTS project has a unique design that incorporates state-of-the-art technologies used to retrieve highly radioactive sludge from the Hanford K Basins (Figure 2). Creating this development readiness testing project has multiple benefits, most notably reducing technical project risk to the sludge removal process during operations, which offers time and cost savings.

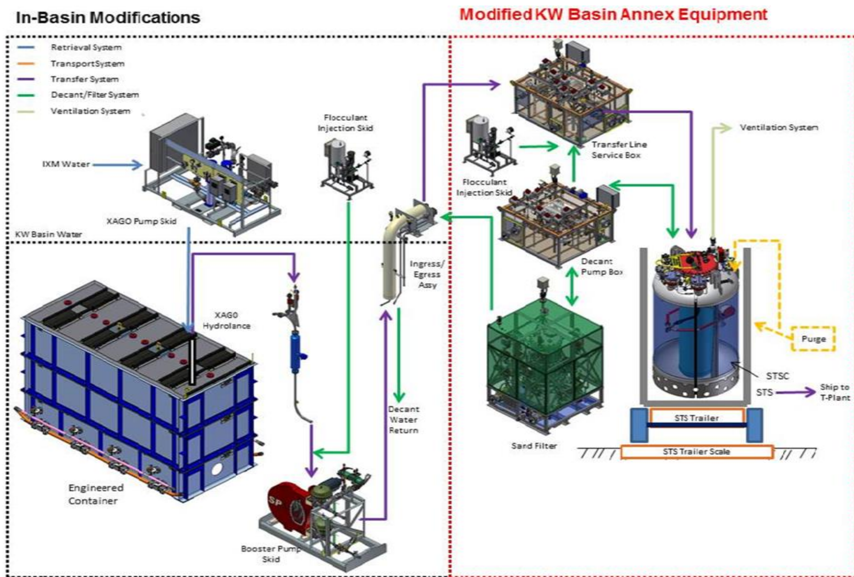

Figure 2. ECRTS Process Overview

Costs are significant if problems are encountered during the actual sludge removal operation. If issues are encountered during this phase, resources are idled until the issue is resolved, resulting in losses of time and productivity of between $2.5M and $3M each month. The effective procurement of tools and testing helped identify and resolve design and operational problems in a safe environment in advance. These issues caught in advance will ultimately help expedite removal of sludge in a timely manner and will help reduce operating “hotel” costs to keep the100 K West Basin regularly maintained while storing sludge.

Value to society. A key attribute in self-performing testing and validation of the ECRTS design has been worker involvement. Operations involvement not only confirmed realistic operation for the equipment but also validated key safety performance features of the overall ECRTS process. Operations personnel were heavily involved throughout the evolution of the ECRTS design; the key role of Operations was to ensure design features could be performed safely. Workers used extensive full-scale mockups to ensure that designs were ergonomically suitable considering the remote underwater work environment. Custom-designed tools were required so operators can perform underwater activities when sludge removal begins such as connecting process hoses and equipment to retrieve the sludge from underwater engineered containers. Once again, the partnership between operations and engineering resulted in a proven design that can be operated safely throughout the execution of the sludge removal mission.

Processes/tools to verify if project benefits achieved. The project maximized the use of unique tools, including the commitment and execution of a fully integrated system testing of all production hardware in a non-radioactive environment at MASF prior to installation. Project management committed to conducting a full-scale integrated test with actual production hardware prior to field installation at the K Basins.

Testing used a non-radioactive non-homogenous simulant that covered the full range of actual sludge properties (dense, abrasive, small particulates, etc.). The simulants were developed using results of lab samples taken of the individual sludge streams from the basins. The purpose was to ensure the testing would rigorously challenge the equipment to perform is required function over a large range of simulant due to the non-homogenous nature of the sludge.

Local fabrication shops fabricated all hardware tested in cold commissioning and successfully passed all factory acceptance testing prior to conducting the integrated test, the benefits of which included the following:

- Corrected and fixed over 264 drawing changes prior to basin deployment off the project critical path.
- Implemented over 42 physical hardware and software changes prior to basin deployment.
- Completed 32 of the 42 changes on safety significant equipment (safety significant is hardware design to prevent nuclear safety hazards and accidents).
- Resolved and corrected approximately 35 equipment non-conformances during cold commissioning.
- Verified all individual fabricated production components interface and work correctly together as an integrated system before being installed.

The commitment to completing this cold commissioning testing resulted in large-risk reduction to the project.

Benefits overcoming complexities. The sludge removal project is one of the most challenging projects on the Hanford Site. Because sludge removal work has never been performed, it took a team of experts from various backgrounds to map out how this would be done successfully. Some of the challenges were creating and modifying tools that would work to safely and compliantly remove the challenging material from an aging basin. Because the basin was built in the 1940s, it has its own set of challenges, including height restrictions and limited visibility, for workers who will be performing the sludge removal work.

Retrieval of extremely abrasive, highly radioactive slurries presented numerous engineering challenges. Historically, pumping sludges resulted in premature failure of virtually all pumping systems.

Retrieval of the sludge had also been historically challenging. Not only was the wide variety of particle size and density a challenge, the overall consistency of the sludge caused the sludge to be extremely difficult to mobilize and retrieve. A proprietary educator technology was identified that claimed to be ideally suited for the sludge mission; customized control systems and instrumentation had to be developed and implemented to prevent plugging of piping during slurry retrieval and transfer operations. Extensive testing culminating in final acceptance testing during confirmed the robust effectiveness of the technology for sludge retrieval and transfer (pumping). Development of numerous specialty tools was also required to facilitate underwater installation and assembly of the ECRTS process equipment.

A major radiological issue identified during testing was the unexpected accumulation of (simulated) sludge material in process piping (Figure 3). The condition would have resulted in extremely high dose to workers had it not been realized during testing.

Figure 3. Unexpected Simulated Sludge Buildup in Process Piping

4. Schedule

The baseline schedule is logic linked and uses DOE-RL's priorities to establish the high-level work priorities. A detailed field execution schedule (FES) was developed, summarized, and used as a basis for the ECRTS baseline schedule. Coding was maintained in the FES to assign each detail activity to a baseline schedule activity. The FES was updated and revised as needed on weekly basis to reflect the most recent project status. Monthly progress resulting from work initiated, completed, or resequenced in the FES was integrated and aligned with an updated copy of the baseline schedule. This status was a basis for percent complete and earned value reflected in the ECRTS baseline.

Managing the schedule's critical path effectively. The detailed weekly FES review consisted of detail analysis of all activities within 30 days of data date, review of the project critical path and near critical path activities, and review of the driving paths of all fee bearing work scope. Any unforeseen issues were aggressively managed to avoid impact on the critical path. Actions were assigned as issues were identified, such as when replanning was required or delays requiring recovery were encountered. Actions were tracked to completion to ensure minimal impact to the project critical path and complete resolution of any problems.

Schedule-related complexities overcome. Unforeseen corrections in production equipment presented logistic challenges to allow testing to continue without schedule impact. If problems were encountered during testing, detailed work instructions were developed requiring expedited engineering, nuclear safety, quality assurance and work control management approval prior to implementation in the test bed. In some instances, spare parts were used requiring additional detailed documentation on the spare systems to reflect the altered configuration. Orchestration of the extremely complex testing was a daunting undertaking that required incredible attention to detail and thoroughness, while at the same time adhering to highly scrutinized schedule constraints.

Effective management schedule contributing to project's success. With support from management at all levels and disciplines – from the President down to first-level managers – all personnel used the ECRTS schedule as a management tool. The schedule was used to manage various aspects of the project, not just to report status at a point in time. With effective upfront planning, thorough weekly review of schedule activities, and aggressive monitoring of critical and near critical activities, management ensured that personnel were focused on the desired activities to maintain effective progress against the baseline.

5. Cost

Processes/tools to determine and manage project cost. The project baseline was established using an integrated cost and schedule Performance Measurement Baseline (PMB) within the framework of CHPRC's certified Earned Value Management System (EVMS), which manages the project control system by providing the processes that define the scope of work, document the plan to execute work scope, measure performance against that plan and maintain the planning baseline for CHPRC Contract Number DE-AC06-08RL14788 as set forth by DOE Richland Operations Office (DOE-RL).

The project control system is an integrated process that consists of methods, procedures, and automated software systems (tools) necessary for effective management and control of the CHPRC baseline. C

The PMB provides the life-cycle cost, schedule, and scope of work to accomplish the ECRTS scope. The ECRTS schedule is integrated within the overall CHPRC PMB baseline schedule to ensure interdependencies of activities with other projects are properly reflected in the integrated schedule.

In conjunction with scope and schedule planning, appropriate budgets for CHPRC work are established using the cost estimating process that identifies resource requirements for each control account (CA). Estimated resource types and quantities are loaded into the detailed schedule in P6 with the result providing an estimate of direct unburdened costs required to complete the contract scope of work. When processed through Deltek Cobra, which applies appropriate adders and escalation, the fully burdened estimates are established as CA budgets upon approval by the cost account manager (CAM). When summarized, these CA budgets form the PMB along with any approved Undistributed Budget (UB). The impact of new or revised CA budgets associated with changes in contract scope, including utilization of undistributed budget (UB), require an approved contract modification and review and approval through the CHPRC change control process prior to incorporation into the PMB. Changes in CA budgets where use of Management Reserve (MR) is appropriate, while not a contract modification, also require baseline change control process review and approval prior to implementation.

CHPRC conducts performance measurement and analysis as a function of the EVMS established to maintain a baseline plan and measure performance against the baseline. These milestones are accomplished by applying standard earned value analysis methods. The PMB schedule is the baseline plan established for routine tracking to generate objective earned value measurement data for each activity.

Objective earned value measurement begins with selecting the appropriate EVT, which is generally dependent on the nature of the scope to be performed. For scope with specific measurable tasks, discrete EVTs such as 0/100, 50/50, and percent complete would be appropriate. With selection of the percent complete EVT, appropriate ROP must be defined and strictly followed to ensure performance is accurately reported.

Earned value, or BCWP, is determined monthly and compared to the BCWS and ACWP to provide schedule and cost performance status.

CV and SV exceeding established thresholds are analyzed to determine cause, impact, and required corrective actions.

ETC for the work that resides in the current fiscal year are developed monthly by the CAM using the earned value performance data and other realistic information. Comprehensive updates to ETCs are done annually as part of the annual PMB update process.

The results of the monthly earned value performance status and analysis are documented in the cost management system and standard templates and forms for internal and external review and reporting. Structured by the Work Breakdown Structure (WBS), PBSs, and other formats as required, the documentation includes earned value cost and schedule performance measurement data, VARs, scope and accomplishments status, milestone status and deliverables, and problems and issues. The data are summarized in the system to support defined internal and external reporting levels. Errors in reported monthly earned value performance are corrected in the cost management system the next available reporting period.

Each month, the Project uses Deltek Cobra to integrate cost, planned values, and earned value to produce a variance summary, down to the WP level, with roll-ups at each higher WBS level. CV or SV are flagged when they exceed the thresholds established for Level 1 and 4 of the WBS. In cases where both the dollar threshold and the CPI/SPI limits are exceeded, written variance reports are required. It is the responsibility of the appropriate CAM to provide the required variance reports and to develop and implement corrective action plans if needed.

VARs are prepared for variances that exceed thresholds and accomplish the following:

- Identify the problem and cause (address why the problem occurred) and address the impact or potential impact on the CA and other elements of the WBS.
- Identify corrective action, responsible party to implement corrective action, how corrective action is to be implemented and anticipated tradeoffs.
- Identify the timeframe when the positive effects will be manifested.
- Address potential impacts to the estimates to complete and estimates at completion.

Effective management contribution to cost. The ECRTS system consists of dozens of fabricated equipment skids that were grouped into a total of twenty sets of firm, fixed, priced (FFP) procurements. To ensure each of these procurement sets were delivered on time and within budget, the project used the MASF test facility to validate concepts, modify test articles utilizing fabrication capabilities within MASF, re-test, and ultimately provide design documents and procurement specifications to minimize changes during production hardware commissioning.

Extensive management of the fabrication subcontractors was implemented by holding weekly status meetings to ensure challenges were immediately addressed, schedule delays were minimized or schedule recovery actions were established in timely manner. In addition, engineering and quality assurance personnel were on site at fabricator’s facilities to ensure equipment was fabricated to design requirements.

Cost-related complexities overcome. The availability of MASF as a full-scale test facility was instrumental in ensuring production equipment was delivered on time and within budget, enabled assembly as designed, operated within the design specification prior to installation in the field, and minimized overall risk of equipment not operating effectively/efficiently to achieve project specifications.

6. Scope

Processes/tools to document project scope. An alternatives study was initially performed to identify design solutions for retrieving the sludge from the K Basins. A follow-on technology maturation plan was prepared to guide detailed test activities; the scope of the technology development testing focused on confirmation that the selected technologies used in the ECRTS design would be suitable to achieve the sludge retrieval and transfer mission. A subsequent overarching test strategy document roadmap was prepared to depict the testing project life-cycle details, including final validation of the selected technologies.

Processes/tools to manage scope and project success. Collectively, the technology maturation plan and test strategy document were used to develop a detailed project schedule for tracking progress. The field execution schedule was optimized to effectively compact the testing time line to ensure a successful design. Progress on the mapped test activities was monitored weekly to avoid unexpected project delays.

Deviations from planned test activities were evaluated by engineering management to determine cost/benefit of test activities beyond baseline plans. Follow-on actions were developed and aggressively managed to maximized technical benefit to the project's success by eliminating technical risk.

Scope-related complexities overcome. The ECRTS technology development acceptance testing was performed using actual production equipment destined for field installation in the customer's operating facility. Integration of the production SSCs produced by three major NQA-1 qualify fabricators presents obvious potential problems (e.g., incorrect interface alignment, fabrication errors not caught during fabricator/factory acceptance testing, etc.). Disciplined configuration control of any changes made to the production equipment was required to ensure the final engineering documentation matched the production equipment. Complete documentation was managed using project-specific redline control requirements for consistency and thoroughness of all configuration changes.

Control of production material under test and retained as spare parts was also required to prevent co-mingling with other similar, non-quality SSCs. The stringent material control is required to retain the quality pedigree The production material was purchased with prescriptive quality requirements; co-mingling with other similar, but non-quality items is not allowed per company quality control policy. A project-specific procedure was developed defining detailed requirements for maintaining inventory control.

Unexpected issues encountered during the final technology development readiness testing resulted in creative re-sequencing of test scope/activities to prevent schedule impacts and minimize re-testing. Re-test sequencing of numerous issues was consolidated to the extent practical to maintain effective and efficient re-testing.

7. Stakeholders

Figure 6. Technology Exchange with DOE Oak Ridge Stakeholders

Key stakeholder project interest. Many stakeholders have been vocal with their input on cleanup priorities. This project was a direct result of advice ranging from ensuring safety remained the biggest priority to moving sludge away from the Columbia River. Stakeholder groups include the Hanford Advisory Board (HAB), Oregon Hanford Cleanup Board, Heart of America, Hanford Challenge, Columbia Riverkeeper, Hanford Communities, the public and others such as the local Native American tribes. CHPRC Communications and Environmental teams work with DOE to engage stakeholders using a variety of tools such as meetings, publications, tours, open discussions to provide information (Figure 6). In turn, stakeholders become educated so that they can provide informed input about the cleanup.

Processes/tools to manage stakeholder expectations and communications. In conjunction with the testing at MASF, management and CHPRC Communications hosted over half a dozen tours in the last year to discuss project progress to stakeholders, media and oversight committee members. These tours and progress briefs were instrumental in visually demonstrating successful, timely progress in the deployment of the technologically unique ECRTS process. As a result of the tours and communication updates on the project, stakeholders have provided feedback to DOE, and they also understand better the value of demonstrating technology readiness for the high hazard, one-of-a-kind designs for removing the sludge and reducing environmental risk to the river corridor.

Stakeholder expectations and communications management. CHPRC Communications continues to work with stakeholders in the public forum, including HAB and public meetings, to receive feedback and requests for tours and presentations. Once the need for additional communication is identified by DOE, CHPRC Communications works with the CHPRC Project Team in developing presentations on DOE’s behalf, along with project photos, videos and factsheets that are shared on social media, press release, newsletters and other external publications that reach stakeholders.

Effective management of stakeholder contribution to project success. CHPRC Communications continues to support DOE to ensure that stakeholders are engaged in project updates. In one example, CHPRC Communications learned that the HAB desired more detailed information about the construction of the K Basin Annex. CHPRC Communications worked with DOE and coordinated a tour for the HAB members in which they viewed inside the annex and learned about the project directly from project managers.

Stakeholder-related complexities overcome. CHPRC Communications understood how significant this project was and continues to be with stakeholders. They continue to work on updating stakeholders in various meetings and presentations to ensure they recognize that safety remains the biggest priority, that they understand the complexities of the project and that they understand what the next steps are to complete the project.

8. Risk

CHPRC's Risk Management Procedure provides the process and tools to develop the overall Sludge Treatment Project risk management. It complies with the CHPRC risk management process, identifying events that could have an adverse impact on performance against the cost and schedule baseline, as well as opportunities that can have a positive impact on the cost and schedule baseline. The process includes planning and executing actions to avoid the occurrence of negative events or reduce the likelihood and/or consequences of negative events. The process takes input from the Risk and Opportunity Assessment provided by the hazards assessment activities.

Even though the ECRTS process design had been extensively vetted using ~95% equivalent test article configuration, numerous issues were discovered during the testing phase.

Processes/tools used to document risks. CHPRC's Risk Management Plan (RMP) provides the processes and tools by which project schedule, cost and technical risks are assessed, monitored, and reported. This includes risk documentation, implementing risk handling strategies to prevent or minimize the potential of a risk occurring or to implement risk recovery actions if the risk does occur, and risk monitoring/reporting. The RMP is the governing document for the risk management process for CHPRC, including Capital Asset Projects. CHPRC's Risk Management Procedure establishes the process to plan, document, and communicate risks throughout the life of the project. Once initial risk elicitation, identification occurs, risks are assessed for potential impacts/consequences and cost and schedule impacts are quantified utilizing a Monte Carlo analysis. Controlled risks identified as "Key Project Risks" are required to have handling strategies reflected and coded in the baseline.

In addition to the Risk Management process, a technology maturation plan, a roadmap for developing the technical maturity of designs for ECRTS process design was developed assuring logical and systematic approach to design development, technical risk mitigation and issue resolution, and follows the direction and guidance provided by DOE's Technology Readiness Assessment (TRA)/Technology Maturation Plan (TMP) Process Guide.

Risks identified through the RMP process and the TMP are captured in CHPRC's risk register. The Key Risks are identified as defined by CHPRC Risk Management Procedure and are listed below.

Processes/tools used to manage risk. Management Reserve (MR) is established to manage and mitigate risks that are solely identified, controlled, and proactively managed by CHPRC. MR requirements are calculated based on the Monte Carlo outputs compared to the desired confidence level. MR is established for both schedule and cost reserve. Allocation of MR is documented in a Baseline Change Request (BCR) subject to the approval of the CHPRC Change Control Board (CCB) and utilizing the CHPRC baseline change management process.

Effective risk management contributions to project success. At the beginning of the project, the project team held risk elicitation meetings to identify potential risks and unknown events throughout the project. Risk STP-130M relating to operational anomalies discoveries impacting cost and schedule, was realized and a request for an MR draw down was requested and processed through the Change Control process. The additional reserve was utilized for additional resources required to ensure quality and schedule commitments were maintained.

9. Project Change Management

Tools to document/approve changes. CHPRC follows a rigorous change management system to ensure that changes affecting the approved contract work scope, schedule, and budget baselines are effectively managed and maintained to demonstrate configuration control of the PRC Performance Measurement Baseline (PMB). Changes are incorporated in a disciplined, documented and timely manner. Baseline change management is used to assure the PMB reflects the most current plan for performing the authorized work. The incorporation of changes into the PMB ensures that valid performance measurement information is generated for new or revised scope execution, and integration of scope, schedule, and budget is continually maintained.

CHPRC Project Managers (PMs) and Cost Account Managers (CAMs) are responsible for identifying, developing, and submitting a proposed change through review, approval, and implementation. The Change Control Coordinator (CCC) administers the baseline change control activities and verifies the implementation of approved changes. The multi-disciplined CCB dispositions proposed changes to the baseline. A senior executive level manager chairs the CCB. Changes to the baseline are developed, reviewed, and approved in accordance with the CHPRC Project Controls System Description (PCSD).

Effective change management contributing to project success. CHPRC's effective management of change contributed to the project's success. The overall ECRTS project was converted to a Federal Capital Line Item Project after construction had commencement. The change management process was utilized to break out the MPAT project into its own Work Breakdown Structure, recode the project as part of the overall ECRTS Line Item Project, implement DOE Critical Decision-2 (CD-2) baseline estimate, correct coding errors from initial implementation for the Line Item and convert the MPAT Project from other project costs (OPC) designation to a total estimated cost (TEC) designation per customer direction. Additional changes include Base Year Shifts, Revisions to Schedule Calendars and overhead rate Changes. These changes were developed, documented, approved and implemented following the CHPRC Change Management process.

10. Lessons Learned

The technology development readiness project was in response to Government Accounting Office recommendations to DOE for new projects. The GAO strongly suggested that DOE adopt proven methodology for deploying new technology in the DOE complex such as used by NASA and the Department of Defense; key to the recommendation was thorough validation of new or innovative technology prior to installation/operation. This approach is intended to minimize potential fatal design flaws before field deployment to avoid wasteful expenditures of tax payer dollars.

Four previous STP sub-projects were highly successful in large part to the detailed testing performed to validate unique design prior to field deployment. In all of these past projects, final acceptance testing of production components and systems at MASF were in a full-scale arrangement prior to field installation and operational startup. In all instances, the actual field work was performed in much less time than expected and with no major issues.

Processes/tools capturing lessons learned. The MASF Pre-Operational Acceptance Test was performed using a ~1,000 page detailed test procedure. The completed test procedure resulted in excess of 7,000 pages of detailed test data and supporting information. Anomalies identified during testing were documented on test deficiency reports (TDRs).

Integration into the project. Test deficiencies were resolved within the TDR or translated to formal systems/processes for resolution (e.g., Quality Assurance Non-Conformance Reports [NCRs]), redline configuration control of configuration controlled drawings, revision of fundamental engineering calculations and reports, etc. A roadmap to correct each issue was captured in the TDR and required approval by the respective Design Authority as appropriate (hardware changes, software control system changes, etc.). Testing was not declared "complete" unless all TDRs were either resolved during testing or transferred to a subsequent formal system for closure at a later date.

Integration of lessons learned contribution to the project success. Errors caught before final field installation in radiation area where correction would be extensive, hazardous and time consuming, depending on the particular field "fix." Evaluation prior to execution of the technology development readiness project suggested a savings of 91 days equating to an overall $11.3M cost savings; this number is compared with direct installation of ECRTS process equipment and resolution of the unforeseen problems in a contaminated, radioactive environment.

Key lessons learned for the project and/or organization. Through the installation and performance of ECRTS technology verification acceptance testing at MASF:

- 264 drawing changes were implemented
- 160 test deficiencies were identified (53 procedure changes, 42 design hardware/software changes, of which 32 were associated with Safety Significant, Quality Level 2 equipment/processes/procedure steps)
- 35 NCRs were initiated.

Associated equipment changes, TDRs, and the NCRs are documented in the comprehensive MPAT test report. The changes and discrepancies to the hardware and system interfaces would have made direct-to-basin equipment deployment significantly longer and more difficult to implement if it would have been performed in the contaminated KW Basin and the KW Annex active construction area.

Testing successfully verified the process equipment design, the overall operational performance of the ECRTS Process, and the integration of the individual systems, structures, and components with one another to form a complete and functional ECRTS Process system. The testing team discovered and worked through challenges that provided valuable lessons learned, including but not limited to the following:

- Importance of extended submergence for critical instrumentation that is located underwater (Instrument Spool flow meter multiple failures following pool submergence)
- Expansion joint leak testing prior to contaminated service and custom backing rings to ensure maximum sealing surface for expansion joints
- Use of hose protectors where pump action may cause hoses to contact each other or piping components to prevent damage and premature failure
- Use of diodes where solenoid power draw may lead to a pull down of control voltages
- Use of hard-wired connections in lieu of multiplexed networks for signals that are important and time sensitive
- Importance of impulse pressure resistance for pressure transducers (sludge booster/transfer pump discharge pressure transducer failure)
- Incorporating TDR/and redline procedure changes from MPAT procedure into KW Basin pre-operational acceptance testing (KPAT) procedure (significant accomplishment to “testing the test” so that the field acceptance testing in the KW Basin testing environment runs smoother)
- The significance of performing an integrated systems test (the closer to full scale, the better) in a clean, relevant environment to ensure/verify system capabilities and operation prior to radiological field deployment.