A Guide for Successful Test Facility Installation and Operation: The Hanford Waste Treatment and Immobilization Plant (WTP) Pretreatment Engineering Platform - 9128

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ABSTRACT

In 2006, the U.S. Department of Energy Office of River Protection (ORP) and Hanford Waste Treatment and Immobilization Plant (WTP) prime contractor Bechtel National, Inc. commissioned an External Flowsheet Review Team to provide an extensive and critical review of the WTP design bases and flowsheets. The External Flowsheet Review Team recognized that although the pretreatment leaching and filtration processes worked at a bench scale, these processes had not been demonstrated at an engineering scale [1]. A response plan was prepared to address these issues. The plan included modeling, waste characterization, bench scale testing, and engineering scale testing [2]. The Pretreatment Engineering Platform was developed to perform the engineering scale testing. This paper describes the management processes used to complete the successful installation, startup, and integrated testing of the Pretreatment Engineering Platform. Included in the paper are the best practices that reduced project risk and overcame challenges encountered during successful execution of this important project.

INTRODUCTION

During their detailed review of the WTP flowsheet and design bases, an External Flowsheet Review Team comprised of experts from academia and industry raised two major concerns with the combined ultrafiltration and leaching processes [1]. Both of the concerns related to the limited experience and experimental data on the performance of these important unit operations. The EFRT was concerned that design basis permeate flux rates would not be achieved from the ultrafiltration system. Additionally, they questioned the adequacy of the mixing system and postulated that the design basis aluminum and chromium leaching cycle times would not be achieved [2].

A testing program that included process modeling, characterization of Hanford tank waste samples, laboratory-scale testing of these samples, and engineering scale testing [2] was developed to address these concerns. A team with thorough knowledge of the chemical process and design was assembled using engineers, modelers, and operations experts from Bechtel National, Inc. and URS Washington Division, and researchers from Pacific Northwest National Laboratory (PNNL) to implement a testing program and deliver the results required to address these complex issues.

The Pretreatment Engineering Platform is a 1/4.5 scale facility designed, constructed, and operated to test the integrated leaching and ultrafiltration processes designed for the WTP, using non-radioactive waste simulants. It is located on the PNNL campus in Richland, WA. The Test Facility has a footprint of 464 square meters (5000 square feet) and has two operating levels. Approximately 1500 instruments – including 400 NQA-1 qualified instruments – monitor process operations and provide data needed for decision-making. Over 1100 manual and automatic valves are used to direct flow of simulant, water, steam, and reagent chemicals throughout the plant. Images of the Facility are provided in Figure 1, below, and Figure 2, page 3.

Fig. 1. Upper Operating Level of the Pretreatment Engineering Platform.

Design and fabrication was performed in Carlsbad, NM. Detailed design began in January 2007. Following fabrication and factory acceptance testing, the first of 16 equipment skids was shipped in February 2008. Installation was completed in May 2008 with completion of integrated acceptance testing in September. Following a series of integrated water tests and simulant shakedown, integrated testing to demonstrate leaching and ultrafiltration processes at an engineering scale began in January 2009.

Fig. 2. Ultrafiltration Loop Pumps on the First Operating Level.

An integrated project team comprised of staff and management from Bechtel National, Inc., URS Washington Division, and PNNL drove the successful completion of equipment installation, startup, systemization, and testing of the Pretreatment Engineering Platform. This paper describes the management processes used to execute the work, and addresses many of the best practices used to overcome challenges and reduce risk, including:

- Emphasize safety
- Identify and use lessons learned
- Establish and use an integrated management team
- Identify and develop key personnel
- Perform a management review of readiness to begin testing
- Use project management techniques that work
- Implement a joint test group to control testing

EMPHASIZE SAFETY

Employee safety was of primary importance to the project. Team members were empowered to protect themselves, their co-workers, the public, the environment, government facilities and equipment from harm or damage. All employees were authorized to stop work or step back when unsafe conditions, uncertainty, or insufficient clarity regarding the work to be performed were observed. Through continuous emphasis of safe work practices, close coordination between operations staff and craft personnel, daily work schedule meetings, and use of pre-job briefings prior to each installation or testing evolution, there were no lost time accidents despite the project's aggressive schedules, and parallel equipment installation, modifications, and acceptance testing.

IDENTIFY AND USE LESSONS LEARNED

In order to reduce project risk, the Pretreatment Engineering Platform management team recognized the need to identify and implement lessons learned from other engineering and pilot scale testing activities. WTP and the DOE Office of Engineering and Technology collaborated to host a Test Facility Technical Exchange with the goal of improving safety, efficiency, and effectiveness of test facilities, programs, and operations across the DOE Complex on December 4 and 5 of 2007. The exchange included approximately 60 individuals from across the DOE Complex, National Laboratories, and industry.

Meeting participants highlighted 32 lessons important to test facility operations [3, 4]. Many of these lessons were incorporated into the planning basis for the Pretreatment Engineering Platform installation, shakedown, and integrated testing. Several of the most pertinent lessons include:

- <u>Implement a Joint Test Group:</u> The participants recommended use of a Joint Test Group to review preliminary test results, ensure the integrity of the testing activities, and provide documented direction to the shift manager for daily testing evolutions. Additionally, the Joint Test Group would have the authority to make changes to the testing program, within the bounds of the facility's safety envelope. These recommendations formed the basis for the Pretreatment Engineering Platform Joint Test Group's roles and responsibilities.
- <u>Perform Management Assessment(s) Prior to Testing:</u> Participants identified the performance of a management assessment of readiness to begin testing as critical to the success of any engineering-scale testing activity. Elements of the assessment would include readiness of equipment, staffing, training, and the maturity of procedures and test instructions. Pretreatment Engineering Platform management used a graded approach recommended by the participants to develop the scope and approach of the management assessment.
- <u>Communicate:</u> The importance of proactive communications for any test facility was stressed, especially for facilities the size and complexity of the Pretreatment Engineering Platform. Communications within the project as well as with senior management and external stakeholders were both considered important.

  Although interest was expected, the high level of interest expressed by external organizations was not expected. The Test Facility has hosted tours from the Defense Nuclear Facilities Safety Board, DOE Headquarters, local DOE, Hanford Site stakeholders and regulators, the media, and senior corporate management.

  The management team established new measures to coordinate tours. They developed standard badging and visitor escort routines, while continuing the performance of work at the Facility. WTP and PNNL communications departments jointly prepared an information sheet to provide visitors with key facts and schedule information.

  E-mail communications and more formal briefings were also used. Frequent schedule and status e-mails were prepared for local ORP, WTP, and PNNL management: weekly during equipment installation and daily during testing. Daily shift instructions were distributed from the Operations

Manager to all individuals staffing the Pretreatment Engineering Platform. Monthly briefings were also provided to corporate leadership and senior WTP and PNNL management.

- Simulant – Formulation, Handling, Manufacture, and Disposal: The meeting participants agreed that the physical and chemical properties of simulant used during engineering-scale testing need to be carefully vetted. Additionally, manufacture of the simulant had to be carefully managed to ensure vendor compliance with specifications. For the Pretreatment Engineering Platform, simulant formulation underwent a rigorous review and concurrence process by key staff at WTP, PNNL, and ORP before the purchase order was released. Further, PNNL identified a single point of contact to control simulant specification and manufacture oversight. WTP technical staff were involved at every step of the simulant specification, and provided oversight at the manufacturer's facility.

  In addition, the WTP Process Engineering and Technology Department established the role of Simulant Coordinator with responsibility to review and coordinate the use and development of simulants in all testing programs from the laboratory to the full-scale WTP.

- Controls and Instrumentation, Including Programming Verification, Will Take Longer than Expected: The management team expected this issue to arise, and it did.

  Calibration of approximately 400 instruments to NQA-1 standards – including receipt of calibration certificates – took significantly longer than expected. An NQA-1 qualified service provider sent two calibration teams to Richland, WA to calibrate these instruments over an intensive two-week period. Receipt, review, and approval of the calibration certificates turned out to be a protracted process, requiring more staff time than originally estimated.

  The Facility's control code did not arrive at the expected level of maturity. The custom programmable logic controller used at the Pretreatment Engineering Platform was a first generation control system developed by a reputable global automation technology company. Nonetheless, an additional staff year of effort by PNNL programmers was required to mature the code to a point where it would effectively control the system, and provide functionality needed to efficiently execute the integrated tests. In addition, verification of code implementation, instrument and interlock operability, and subsequent control loop tuning also took longer than scheduled.

  During equipment design and fabrication, the management team was proactive in requiring submittal of control system screen shots, retaining key local staff involved in specifying the control logic, and providing a detailed review of documentation supplied by the vendor. It is clear, however, that the management team should have provided additional supervision to the vendor developing the control code. Further, additional training should have been provided to the programming staff to ensure fluency in the underlying computer code. Co-locating a client representative with the control system developer would, in hindsight, have been useful.

- Good Conduct of Testing/Operations is Essential: The participants agreed that a graded, documented conduct of operations approach is essential to ensure safety and effective test facility operations and testing evolutions. This approach includes clearly identified roles, responsibilities, authorities, training, startup and operating procedures, test procedures and implementing instructions, and a document hierarchy.

  In response, PNNL prepared and implemented a conduct of operations plan [5] based on DOE Order 5480.19, *Conduct of Operations Requirements for DOE Facilities.* WTP also embedded staff experienced in conduct of operations principles with PNNL testing crews to provide mentoring and assistance to PNNL Shift Supervisors and Lead Test Engineers in the execution of operations and testing evolutions, as well as to provide an increased level of shift staffing. Conduct of operations mentors from PNNL and the WTP were also used to observe evolutions and provide feedback to the management team

ESTABLISH AND USE AN INTEGRATED MANAGEMENT TEAM

Peter Senge describes great teams as "…groups of people who, over time, enhance their capacity to create what they truly desire to create [6]." Typically, Senge explains, it takes time for groups of individuals to develop the ability and understanding to work as a whole. In the case of the Pretreatment Engineering Platform management team, development into a cohesive team had to occur quickly. The team consists of staff from ORP, PNNL, and the WTP, and includes functions such as technical oversight and coordination, equipment installation, test planning and execution, operations, engineering, and project management. Use of an integrated management team – with WTP maintaining the project management function, among others – was critical to the moving the project forward, as all three organizations had significant roles to play to ensure the success of the project. The project's Organizational Chart is provided in Figure 3 on the next page.

The intent of the management structure was to provide rapid response to emerging issues. The WTP served as both customer and design authority, and developed the underpinning scope and testing specification. Issues identified during installation and integrated testing had to be resolved in real time and in a manner that ensured the technical veracity of the solution. During installation, a process was established that allowed the WTP technical authority to evaluate issues and the recommended solutions, as well as work with technical experts and construction management to concur on the recommended solutions or provide alternate direction. This closely coupled process allowed rapid issue resolution, and lead to more efficient installation and testing. Additionally, this process was incorporated into the scope of work and Project Execution Plan to ensure there was sufficient control of scope, but was sufficiently flexible to support the expedited schedule.

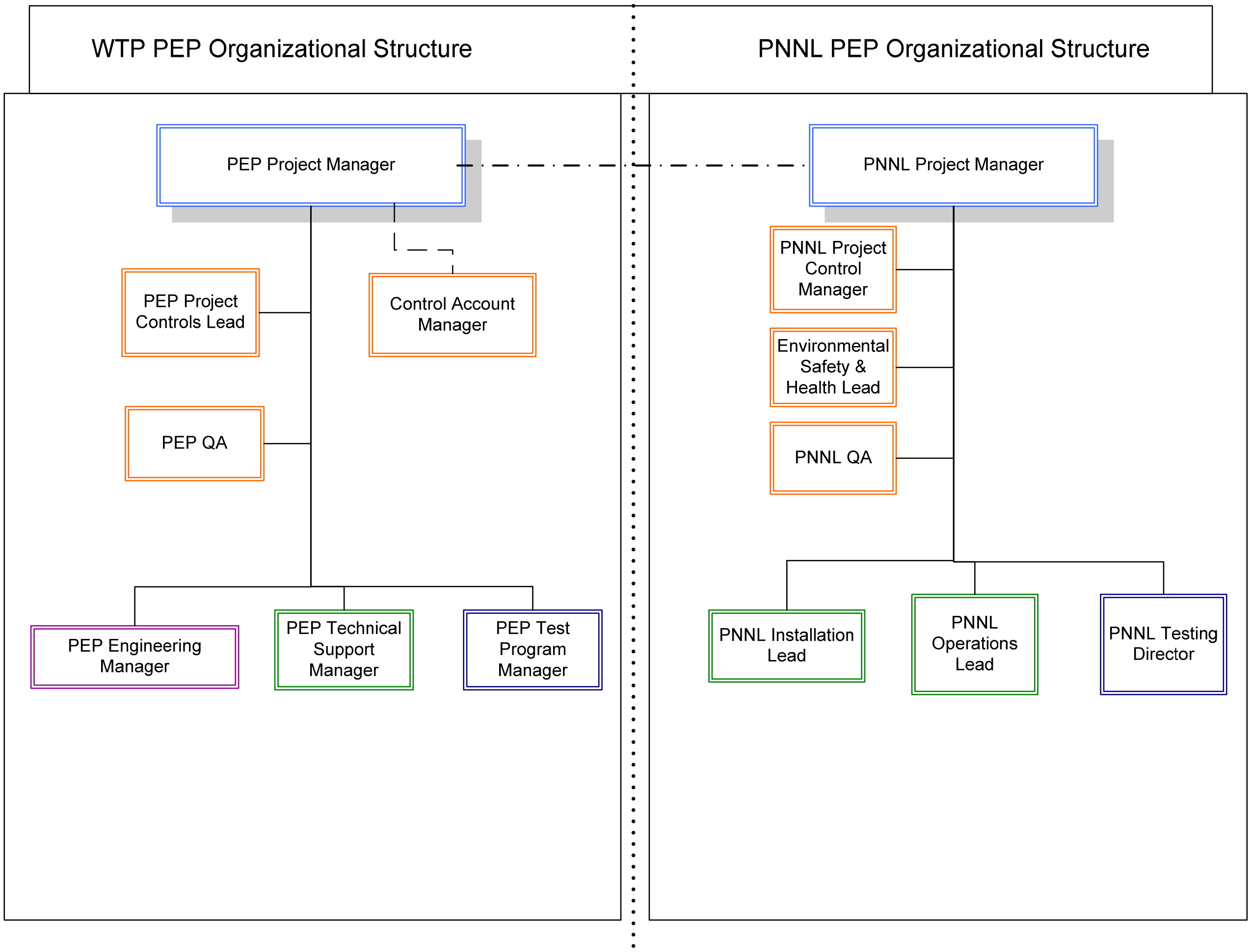

Fig. 3. Pretreatment Engineering Platform Organizational Chart

Team Development Model

The Forming Storming Norming Performing team development model was published in 1965 [7], and accurately describes the development of the Pretreatment Engineering Platform management team. Although not new, development of any group into an integrated team typically will undergo this transformation. Project managers and other key task leaders should expect the team to progress through the following stages:

- Forming: In this stage, there is high dependence on the team leader for guidance and direction. Individual roles and responsibilities are unclear, and the leader must be prepared to answer questions about the team's purpose, objectives, and external relationships. The difference in organizational cultures between WTP and PNNL and initial mistrust regarding the ownership of risk were evident. The principle outcomes of this stage were the establishment of a common understanding of the scope of the project, and initial development of the Project Execution Plan (discussed below).
- Storming: In the second stage of team development, clarity of purpose increases, but uncertainties persist. Group members experience conflict and disagreement, and compromises may be required to enable progress. The first draft of the integrated schedule, and the initial set of assumptions for equipment installation and integrated testing were prepared during this period. Through development

of these documents, the team matured in its understanding of the requirements and better understood the organizational values brought by the various team members.

- Norming: In the third stage of team development, roles and responsibilities are clear and accepted, and agreement and consensus is developed. Processes and group working style are also developed. The Project Execution Plan was approved during this stage. Equipment installation was initiated in this stage and continued through the next stage. Change control trends for acceptance testing and integrated simulant testing were developed in this period.
- Performing: In the fourth stage, the real work of the team is accomplished. The team is strategically aware and has a shared vision of the work they must accomplish. Baseline change proposals for acceptance testing and integrated simulant testing were prepared and approved by WTP management. In addition, Integrated Water Testing and simulant testing was performed in this stage of team development. The management team understood what was required, and was working in concert to complete the work as efficiently as possible.

Themes of Successful Management

As the progression thorough the stages of group development occurred, the management team began to exhibit several of the six themes of successfully managing technology identified by Maidique and Hayes [8]. These authors indicate that while few organizations exhibit excellence in each of the six categories at any one time, organizations that successfully manage technology score highly. The themes for which the Pretreatment Engineering Platform project team exhibited excellence include:

- Focus: The management team and staff were highly focused on the clear objectives of the project, which were to demonstrate the leaching and filtration flowsheets and obtain data needed to support procurement of the ultrafilters, spiral heat exchanger, and the ultrafilter loop pumps. Emphasizing these priorities with the staff ensured the team's focus remained consistent over time. This focus was internalized by the staff and articulated in the understanding that they were "doing something important."
- Adaptability: The well-defined testing program and execution schedule was balanced with the willingness and determination to undertake change when necessary. As part of the planning process, key staff members visited the fabricator to gain a better understanding of how to perform the skid installation at PNNL and reduce risk to the schedule. Plans to provide sequential staff training were revised to be concurrent during Integrated Water Testing in response to schedule pressures. When the programmable logic control system did not function as expected, PNNL staff revised the code to provide functionality. Plans to publish data supporting engineering procurements were changed to better support the procurement schedules. Test conditions were matured through simulant shakedown in response to operational experience. The team's focus and understanding of objectives led to inherent adaptability.
- Sense of integrity: Staff and management exhibited flexibility as necessary to maintain schedule, reduce risk, and keep work within budget, but were unwilling to compromise on safety, final implementation of conduct of operations, or quality of results.
- Hands-on management: The management team was heavily involved in every step of the project. For example, the Startup Manager and Operations Manager essentially provided near continuous coverage at the facility. Frequent communication with PNNL and WTP management was commonplace (weekly at first, then daily during testing). Additionally:
    - An operations and status conference call was held daily to ensure work scope was understood and prioritized.

  - Task owners and management reviewed the detailed punch list three times each week.
  - Schedule status and review was performed twice each week.
  - The well-being of staff was important. For example, celebrations were held upon completion critical project milestones. Additionally, a family day at the Facility was held in order to provide an understanding of where family members were working and the importance of their contributions.

Ultimately, as a means to reduce risk and provide greater project flexibility, shifts were staffed with individuals from PNNL, WTP, and ORP, with each organization providing important perspective to equipment operation and testing.

IDENTIFY AND DEVELOP KEY PERSONNEL

Personnel development is a key element of the URS Washington Division business model, and efforts were made to bring this approach into managing equipment installation and testing. With complex projects with aggressive schedules, however, personnel development has to be coupled with the need to achieve project goals in minimal time.

In order to mitigate risks associated with installation, startup, shakedown, and operations and testing, key personnel from the WTP, PNNL, and ORP who were associated with the equipment design and fabrication, simulant development, and early test planning activities were brought forward into the next phases of the project. This leveraged their knowledge of the Facility design and provided these staff with startup and operating experience.

A proactive approach furthered the development of these individuals, reducing project risk and increasing operating efficiency.

- Individuals involved with specifying the equipment, performing detailed design review, and factory acceptance testing were used to support oversight of equipment installation, and eventually served on the testing shifts or in key test planning and leadership roles.
- The ORP technical representative continued in his role, bringing key input and understanding as to the system design and outcomes needed to resolve the External Flowsheet Review Team issue.
- Experience gained by WTP and PNNL staff involved with developing the simulant recipe was leveraged to support procurement and shipment of the nearly 45 cubic meters (12,000 gallons) of simulant used during shakedown and testing.
- Staff members from the WTP Operations Department were integrated into the operating teams to provide valuable knowledge on the startup and operations of facilities within a DOE conduct of operations environment.

PERFORM A MANAGEMENT REVIEW OF READINESS TO BEGIN TESTING

In the interest of due diligence, a management review of readiness was performed prior to initiating simulant operations, consistent with the outcomes of the Test Facility Technical exchange. The purpose of the review was to assess the project’s readiness to perform simulant operations, and was performed by PNNL line management [9], with oversight by WTP [10] and ORP [11].

PNNL line management's assessment was performed to verify that operating procedures worked effectively and that an appropriate level of rigor had been established to conduct operations safely. The scope of the assessment included:

- Review of operating procedures, test instructions, and underpinning facility documentation
- Interviews with staff to determine the level of process and system knowledge
- Observations of shift turnovers and test evolutions
- Confirmation that a hazards identification and control process was defined and effective
- Reviews of documentation for qualifying operators
- Observations of the Integrated Water Test
- Review of the engineering design process, including disposition of non-conformance reports
- Verification that configuration management had been established and that the process would ensure maintenance of configuration over the life of the project.

The assessment used staff interviews, document and procedure reviews, observations of specific evolutions, field inspections, and system walk downs. Assessment team members were given full access to documents, staff, and the equipment.

WTP's oversight review was performed as part of an ongoing management self-assessment program. The purpose of the WTP oversight review was to provide a structured, documented review of the PNNL management assessment, and to provide the basis recommending authorization for integrated simulant shakedown and testing. Additionally, the readiness of WTP to provide oversight and technical and design authority support was confirmed. Review areas included management systems, operations, environmental requirements, configuration management, engineering test specifications, procedures, training, conduct of operations, and quality.

The purpose of the ORP assessment was to evaluate the adequacy of startup preparations. ORP staff assessed the functional areas of training, equipment configuration, and documents and procedures. In addition, they performed staff interviews and observation of equipment and personnel preparations.

The management assessment began during integrated water testing, while preparations for simulant testing were still in progress, and operating procedures and test instruction were being finalized. This allowed real time feedback from the management assessment team as improvements and corrective actions were being performed. Open issues at the beginning of the assessment included the need to strengthen the conduct of operations culture, fully implement the training program, and fully implement quality requirements for data acquisition and management [12]. These issues are discussed below. All outstanding issues were ultimately resolved, and authorization was granted to proceed with simulant operations [13].

Conduct of Operations

Equipment shakedown and early test operations prior to and during integrated water testing were conducted using a graded Conduct of Operations approach. The intent was to begin shakedown in a startup environment, and gradually implement increased Conduct of Operations rigor as activity progressed. This approach, however, led to personnel receiving inconsistent Conduct of Operations expectations and, in some cases, developing bad habits. The newly formed crews of researchers, engineers, and operators had varying levels of operational experience, and required time to learn and practice the level of operational rigor expected during simulant operations. Improvements in operating discipline was noted during the course of the assessment, and performance was sufficiently strong to enable start of simulant operations. In hindsight, earlier implementation of Conduct of Operations rigor during practice runs would have helped to ensure a higher level of operational performance during integrated water testing.

Training

At the start of integrated water testing, not all staff members had completed all items identified in the training matrix. This was due to a number of factors, including newly assigned personnel having insufficient time to practice and demonstrate proficiency in various plant operations, a lack of emphasis on completion of training prior to the start of integrated water testing, and completion of training paperwork. These issues result from the decentralized approach to completing staff training. A more centralized, intentional approach to staff training would have alleviated this issue.

Quality Requirements for Data Acquisition and Management

Data quality requirements were slow to be implemented, including validation and verification of data management software. This lead to delays while system problems were resolved and quality requirements were met. Additionally, configuration control of the control software was initially lacking, and led to several instances of re-work. These issues, like those identified above were overcome.

USE PROJECT MANAGEMENT TECHNIQUES THAT WORK

Develop a Project Execution Plan

A project execution plan was developed to establish the strategy for conducting installation, shakedown, and testing [14]. The purpose of this document was to ensure integration, and clarify the roles, responsibilities, and authorities between WTP, PNNL, and ORP. The primary project functions (project management, testing, engineering, and quality assurance) performed a detailed review to ensure concurrence with the document and obtain buy-in with the management approach.

In addition, the project execution plan expressed a clear philosophy:

- Fostering a high-performance working environment within an Integrated Safety Management System through open communication, cooperation, and mutual respect. The project manager was charged with guiding the team by communicating project goals and expectations, assigning clear roles and responsibilities, responding to team information needs in a timely manner, making critical decisions in a timely manner, and resolving conflict.

- Team members were encouraged to develop a questioning attitude; participate in the identification and resolution of issues; follow procedures, directives, and similar written documents; report deficient or weak processes; and support improvement initiatives.

- Managers were expected to support employees in meeting these expectations and earn the trust and respect of workers and peers by treating them fairly and consistently. Frequent, focused, and honest communication with employees at the location of the work would enable managers to ensure safe compliant work execution; solicit worker input; resolve issues; promote acceptance of questioning attitudes; authorize employees to step back and stop work; lead by example; and ensure workers are properly trained and have the tools to perform the work as assigned.

- Managers were accountable for all results within their areas of responsibility. Most important are results affecting the people of the project team, their safety, and the overall success of the project team. Oversight of the project was performed using normal ORP, WTP, and PNNL review and monitoring processes.

Develop and Use an Integrated Schedule

Early in the project's planninging process, a detailed integrated schedule was developed, including scope and logic ties associated with equipment installation, acceptance testing, shakedown, and integrated testing. Developing the integrated activities and logic was critical to tracking and reporting progress, communicating to-go work, and establishing the overall scope of the project.

Eventually, the schedule included nearly 1500 separate activities, and provided three levels of detail:

- A one-page management summary schedule
- A 10-page summary schedule that was reviewed weekly
- A 30-page schedule that contained activities of two-day duration and longer.

The integrated schedule underwent a weeklong activity-by-activity review by PNNL and WTP staff and management to ensure understanding of the scope of work, appropriate assumptions underpinning the schedule, and defensible activity durations and logic.

In addition, an external review of the schedule and assumptions was performed. Two independent senior corporate managers highly experienced in equipment installation and startup – one from Bechtel and one from URS Washington Division – reviewed the schedule, activity logic, and underpinning assumptions. This risk-reduction review ensured the proper definition of the scope of work and that the schedule was appropriate. Review comments from both senior managers stated that the work was well scoped and that the schedule was aggressive. Performance of this internal review proved invaluable, providing independent validation of the scope and schedule and confirming good planning efforts.

Earned Value

The WTP work breakdown structure is organized by facility (Pretreatment, High-Level Waste, Low-Activity Waste, Analytical Laboratory, Balance of Facility, etc.), and then by function (Engineering discipline, Operations, Research and Technology, etc). Performance within the WTP earned value management system is reported in accord with the work breakdown structure. From initiation, the Pretreatment Engineering Platform project used resources from a number of WTP cost accounts, across the work breakdown structure. Thus, it was difficult to report progress and earn value.

Consistent with earned value management system requirements, baseline change proposals were developed sequentially for each primary element of the project: design and fabrication, equipment installation, acceptance testing, and integrated testing. Application of lessons learned during previous scopes of work helped develop the baseline change proposals for future scopes of work. For a number of reasons, baseline change proposals took a long time (weeks to months) to be approved. In some instances, baseline change proposals were approved and entered into the WTP Project Management Baseline after the work was essentially completed.

The realities extended durations to approve changes to the Project Management Baseline and of working a sub-project from within a very large project required a different approach to reporting progress in an approved earned value management system. A project-specific tool was developed to track and report performance that incorporated the authorized budget at completion and unimplemented trends and baseline change proposals that were undergoing evaluation. Progress and variance analysis reports were prepared at the summary level, and for each of the primary elements of the project, including design and fabrication, equipment installation, acceptance testing, integrated testing, and oversight and management.

Actual cost of work performed, time-phased authorized budget, performance, and forecast cost were collected and reported based on subcontractor monthly cost and progress reports. Unimplemented trends and baseline change proposals were included in the project-specific tool in order to provide a complete synopsis of the project.

IMPLEMENT A JOINT TEST GROUP TO CONTROL TESTING

As an outcome of the Test Facility Technical Exchange, a Joint Test Group was chartered in the Project Execution Plan to provide review, concurrence, and approval for test documentation and resolution of issues. The Joint Test Group was formed using key staff from WTP, PNNL, and DOE ORP, and included client, project management, operations, testing, engineering, technical support, and quality assurance functions. The primary function of the Joint Test Group was to ensure that testing was compliant with project requirements for acceptance testing, and integrated testing.

The Joint Test Group generally met weekly or bi-weekly during equipment installation and initial equipment checkout. Weekly meetings scheduled throughout acceptance testing and integrated testing allowed progress review and issue resolution. During integrated simulant testing, the Joint Test Group met daily to review preliminary results of testing, and provide timely direction to the lead test engineers and testing teams. Ad hoc meetings, held as required, addressed emerging issues.

CONCLUSIONS

The project management approaches discussed in this paper have directly enabled the performance of testing that is addressing critical uncertainties in the design and operation of key WTP unit operations. The project-based approach to performing integrated acceptance testing, integrated water testing, simulant shakedown, and integrated simulant testing enabled successful task execution, management focus on issue resolution, and cost control. As a result of the engineering scale work at the Pretreatment Engineering Platform, the integrated WTP flowsheet is being better understood, and specific decisions on the procurement of important WTP equipment are being made based on data obtained during simulant testing.

As Theodore Roosevelt said:

> Far better it is to dare mighty things to win glorious triumphs, even though checkered by failure, than to take rank with those poor spirits who neither enjoy much nor suffer much, because they live in the gray twilight that knows not victory nor defeat [15].

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