EM-53 Lessons Learned Bulletin

March 2016

Lessons Learned from Commercial Nuclear Plant Construction

Contact: Johnnie Newson, johnnie.newson@em.doe.gov

Date: 3/29/2016

Statement:

Construction of any facility, such as a nuclear power plant or a large dam, that needs tens of thousands of tons of steel, concrete, and other materials is difficult, and runs the risk of cost overruns if delayed. Nuclear plants were sometimes singled out as particularly susceptible to overruns due to the added quality assurance, regulatory oversight, and complexity issues not seen in some other large infrastructure projects. Some of these large construction projects were not well managed, and did not meet the planned schedule which resulted in higher costs to the plant owners. As orders for nuclear plants began to increase in the 1970s and 80's, and now again in early 2000's, it is apparent that manufacturing of key, large components could not keep up with the order volume, and that skilled and capable craftsmen/tradespeople were not available all the time. The vendor issues, poor construction management, lack of standardized designs, and lack of completion of designs before construction, led to delays. Since the utilities are financing the debt they had taken on in order to obtain working capital to build the plants, the costs increased as the plant schedules are slipping. Schedule delays are a critical element in increasing major plant costs.

Studies of constructing nuclear power plants in the United States indicate that the costs have been increasing due to:

- Escalation of labor and materials
- Poor labor productivity due to lack of qualified vendors with experienced tradesmen
- Increase in the cost of money due to lengthening of construction schedules
- Added cost of structures and systems associated with evolutionary safety and regulatory requirements
- Increase in cost and contingency due to design changes leading to alteration and/or addition of new systems

Lessons learned from the review of the construction of commercial nuclear power plants are applicable to today's large construction Department of Energy (DOE) EM projects including SWPF and WTP (and future projects such as LAWPS). DOE has recognized these issues and addressed them in the updated DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets (soon to be issued) and other recent policy directives.

Discussion:

Current commercial nuclear power plant constructions, the first plants to be built in approximately 30 years, are again experiencing significant delays and cost overruns. Two plants being built by Georgia Power, Vogtle units #3 and #4, have experienced an 18 month delay and a $1B overrun. Similarly, the new Summer units #1 and #2, being built in South Carolina, are 18 months behind schedule and $2B over budget. Several of the large DOE EM's complex projects have also experienced these issues.

At the peak of constructing nuclear power plants in the 1960's and 1970's, plant estimates for construction costs were actually going down due to learning curves experiences with building similar plants by large contractors. The DOE unfortunately usually does not get to experience this benefit, because its major projects are unique, first-of-a-kind technologies and facilities that do not get replicated. New nuclear plants, once again using new designs, are back to experiencing significant delays and cost overruns.

Analysis:

Schedule delays resulting in cost increases to major projects can be caused by a number of reasons. Some of these are:

- Regulatory impact (WTP and SWPF have both experienced DNFSB regulatory creep)
- Quality issues resulting in rework
- Vendor issues with material and labor productivity
- Cost estimate optimism
- Lack of qualified nuclear workers (specifically, nuclear welders)
- Lack of completion of design prior to start of construction resulting in rework
- Lack of freeze on design and construction requirements resulting in rework
- Lack of funding for the entire project causing slowdowns or delays.

In addition to the above, major DOE projects have been delayed by the selection of the technology for their one-of-a-kind facilities. They have been plagued by numerous major technical issues resulting in the stopping of design and construction activities while technical issues are resolved. The rework associated with some of the above issues is a triple threat to cost and schedule, since the original material and labor cost is lost, and additional labor is needed to remove the problem equipment, and then additional cost of labor and material is required to replace the defective equipment.

Initial contracts for commercial nuclear power plants were routinely of the fixed price type. However, it was soon discovered that changes resulting from regulatory, safety, or schedule issues was causing significant change orders to contracts, quickly driving up costs and delaying schedules. Experience determined that cost-plus construction contracts were prudent. The DOE has also changed to cost-plus contracts for major projects, especially for their first-of-a-kind facilities, with the addition of incentive or award fee clauses to attempt to drive schedule and contractor performance to be more favorable.

Project integration is also a key to success in large construction projects. There are three distinct phases to a major capital asset project: Engineering, Construction and Startup/Commissioning. Proper integration between the three phases is vital. Most important, it should be recognized that the design activities of the engineering phase of a project should be as mature as possible prior to construction start, since a relatively minor engineering change can have significant impacts in the construction phase. As an example, a decision was made to begin the construction of the WTP in parallel with the design phase, and significant technical issues have led to significant construction changes, with associated schedule delays and cost increases. That is why DOE's Assistant Secretary has provided recent direction that design maturity should be at 90% on particular projects prior to authorization to begin construction is given.

Actions:

The following are key lessons learned from construction of commercial nuclear power plants and after each is an excerpt from DOE Order 413.3B that addresses each item:

• Owner Responsibility - Owners of nuclear plants are responsible for all elements of construction, scope, schedule, cost, quality, and report to the regulatory authority. The owner controls all contractor actions and activities.
  o In the DOE: "For each project, the appropriate Under Secretary will designate a clear project owner. Each Under Secretary will also establish a clear line of functional responsibility that extends from the Under Secretary to the project owner to the Federal Project Director. This shall be documented in the preliminary project execution plan at CD-1."

• Evaluate Alternatives - Nuclear plant owner conducts an extensive evaluation of market conditions, future power needs, energy portfolio diversification, and competing energy sources before submittal of a Combined Construction and Operating License (COL) to the NRC.
  o In the DOE:
    Conduct an Analysis of Alternatives (AoA) that is independent of the contractor organization responsible for the proposed project, for projects with an estimated TPC of $10M or greater. For projects with an estimated TPC less than $50M, the analysis shall be commensurate with the project cost and complexity.
    Conduct an AoA for projects with an estimated Total Estimated Cost (TEC) greater than the current General Plant Project (GPP) threshold prior to approval of CD-1. For projects with an estimated total project cost less than $50 million (i.e., representing the upper end of the cost range), the AoA shall be commensurate with the project cost and complexity. June 8, 2015
    For Major System Projects, conduct a Technology Readiness Assessment and develop a Technology Maturation Plan, as appropriate. At this stage, each critical technology item or system shall achieve a Technology Readiness Level-4 (TRL-4).

• Project Assessment - Nuclear plant owner must continuously assess the contracted cost and schedule and contract provisions, and report potential overages to their utility regulator (the PUC) and receive authorization for prudency to increase costs.
  o In the DOE:
    When the integrated project team, Program Office, or independent oversight offices determine the Performance Baseline scope, schedule, or cost thresholds will be breached, the Program Office is required to conduct an independent and objective root cause analysis to determine the underlying contributing causes of cost overruns, schedule delays, and performance shortcomings. The root cause analysis will be provided to the PME as part of the rebaselining process to inform the PME's decision of whether to terminate or proceed with the project. Corrective actions shall be identified and presented to the PME for action approval.
    Assessment of CD proposals and Baseline Change Proposals. The committee will use information and data provided by the program and other project management organizations to review and analyze projects before all CDs and BCP are presented to the Chief Executive, Project Management Executive, or ESAAB. As appropriate, the respective FPD or designated program representative (prior to CD-1) will brief the committee as part of the assessment process.

• Baseline Integration of Project Phases (Engineering vs Construction vs Startup &Commissioning) – each phase of the project requires different processes, sequences and resource requirements. Each phase needs to be planned, scheduled and integrated into an approved baseline.
  o In DOE O 413.3B, Appendix A, Section 4.c, CD-2, Approve Performance Baseline: "Establish a Performance Baseline, reflective of identified and assessed risks and uncertainties, to include TPC, CD 4 date, and minimum KPPs. The key project milestones and completion dates shall be stated no less specific than month and year. The scope will be stated in quantity, size and other parameters that give shape and form to the project. The funding assumptions upon which the PB is predicated will be clearly documented and approved."

• Proper Contract Type - In recent nuclear construction, the owners have applied more definitive contracts including a portion of the contract being fixed price (balance of plant), hybrid contracts, open book contracts, and some cost plus contracts.
  o In the DOE:
    Selection of Proper Contract Type – The use of a firm-fixed price contract should be considered if appropriate for services that can be provided with a well-defined scope and schedule. However, for first-of-a-kind major projects (like many of the DOE capital asset projects), the use of cost-plus contracts is advised to avoid the hindrance of processing numerous scope changes as projects progress. The inclusion of incentive and/or award fee clauses can be used to incent contractors in improving performance and driving schedule completions.
    DOE O 413.3B, Appendix C, Section 2, Principles for Aligning Contract Incentives: "In instances where a fixed-price contract is not deemed to be in the best interest of the government and a cost-reimbursement contract is selected, objective performance measures will be used as much as possible to incentivize optimal contractor performance and reduce costs."

• Proper Planning – having an integrated schedule of all activities is vital. Identification and consistent monitoring and attention to critical path activities is key to staying on schedule.
  o In DOE O 413.3B, Appendix C, Para 17, Planning and Scheduling. "Projects shall develop and maintain an Integrated Master Schedule (IMS). The IMS shall be developed, maintained, and documented in a manner consistent with methods and the best practices identified in the Planning and Scheduling Excellence Guide, published by the National Defense Industrial Association, and the GAO's Schedule Assessment Guide (GAO-12-120G)."

• Design Maturity - One of the major changes required by the NRC in 10CFR 52 is having design complete before commencing construction
  o In the DOE:
    Mature Design – the highest level of design completion is needed in order to lower risks in the construction and startup phases. A design change made after construction has started can have significant impacts to the build and startup/commissioning schedules.
    DOE O 413.3B, Appendix C, Para 7a Design Management for Nuclear Facilities: "Projects designated as Hazard Category 1, 2, and 3 nuclear facilities shall achieve at least 90 percent design completion before CD-2 (Approve Baseline).

• Standard Design - The major change in approach in new nuclear plants is that there are standard designs approved by the NRC, standard reactor plant vendors and AE as part of the specific reactor design consortium, and a standardized approach to management of the project with NRC approval.
  o In the DOE :
    Effective Project Management – Ensure that the project scope, schedule and cost is fully understood and managed to success.
    DOE O 413.3B, Appendix C, Section 1, Project Management Principles: "Selection and designation of a Program Manager (see Appendix B, Paragraph 6) is critical as they ensure that all their projects are properly phased, funded over time and that each project manager is meeting their key milestones. Program managers are the advocate; they ensure proper resourcing and they facilitate the execution process. A program manager is responsible for managing programmatic risks and putting mitigation strategies in place to minimize risks to projects. Programmatic risks should be identified and quantified in terms of cost and/or schedule contingency and accounted for within one or more of the projects."

Critical Decision(s): CD-1 to CD-4

Facility Type(s): Construction

Work Function(s): Contracts, Project Management, Technical

Technical Discipline(s): All

Southern Company's Vogtle site in March 2014, with two reactors under construction and two operating in the background.

Construction (and design) continue at the Hanford nuclear reservation in southeastern Washington State

References:

1. Davis, Will, "Nuclear Plant Costs – A Look Back and Ahead", American Nuclear Society (ANS) Nuclear Café, February 16, 2016.
2. Lovering, Jessica R.; Yip, Arthur; Nordhaus, Ted, "Historical construction costs of global nuclear power reactors" ScienceDirect Energy Policy Journal Homepage, www.elsevier.com/locate/enpol , January 11, 2016.
3. Downey, John, "Utility says latest delays to Georgia nuclear plant to cost additional $1B", Charlotte Business Journal, March 2, 2015.
4. Larson Aaron, "Costs and Deadlines Continue to Challenge V.C. Summer Nuclear Plant Project", Powers Magazine, August 19, 2015.
5. DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets, November 29, 2010.