

SR PMO FY20 - AAP
MAJOR PROJECT LESSONS LEARNED:
PDCF, MOX, VOGTLE UNITS-3 & 4, and VC SUMMER UNITS-2 & 3

Following are key lessons learned from four recent major projects. The PDCF and MOX projects were Department of Energy (DOE) efforts and the Vogtle Units-3&4 and VC Summer Units-2&3 were commercial nuclear power efforts initiated by public utilities. Only the Vogtle project is still active though it has suffered significant cost and schedule overruns since groundbreaking in 2009. All four projects were multi-billion-dollar efforts that struggled to achieve satisfactory and properly measurable progress across multiple stages from initiation to commissioning. The lessons learned apply in whole or part to management, engineering, design, procurement, construction, quality, startup/testing, and commissioning.

- 1. Earned Value Management (EVM) system not fully developed (viable Rules of Credit, etc.).**
 - a. Schedules cannot be considered realistic if the EVM system is not rigorously managed and maintained. They will change as the project evolves, this is a certainty. Therefore, risk management and contingency planning/funding is an essential element of managing the EVM and project schedule.
- 2. Unit Rate discrepancies across all construction disciplines leading to repetitive baseline cost estimate revisions.**
 - a. Unit installation rates for construction need to be determined prior to initiation of construction work activities in order to build a sound baseline construction cost estimate. Unit rates need to be originated on a representative foundational basis so that the pertinent production factors can be applied to provide a realistic cost for at least a P6 level-3 schedule (eventually expanded to a P6 level-4 for critical work sequences).
 - b. Clear delineation of direct and indirect labor categories that can support determination of "hands on tools" time. Also, the ratio of direct to indirect labor should be monitored throughout the project.
- 3. Assigned Labor PF (production factors) that were unrealistic and unachievable; often too monolithic in not recognizing specific installation conditions and no realistic appraisal of the current general skill levels of the craft.**
 - a. As any major project progresses, there will be changes in labor PFs for certain work evolutions as the project structures get "built-out" and unanticipated problems with building access, work front congestion/labor saturation, available crane time, and other obstacles become apparent. The goal is to minimize these changes and revise PFs only with firm justification. Trust in the experience and knowledge between Line Supervision, Construction Management, and Project Management will play a significant part in this action. Owner oversight and/or direct involvement will be critical to establishing viable PF's.
 - b. The Project Risk Management Plan should account for this likelihood of change.

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- 4. Lack of acknowledgement of the available labor resources and the need to offer per diem or skill bonuses to specific craft in order to attract sufficient skilled labor categories.**
 - a. The Project must not be permitted to predict and schedule resources that cannot realistically be obtained. This will result in the need to “push the schedule”, which often leads to further excuses for non-performance in corollary activities. Incentives can be of assistance in obtaining targeted craft, supervision, and engineering resources but can also lead to internal strife with non-incentivized personnel.
 - b. A thorough cost-schedule analysis should be performed to determine the proper balance for incentives. Impact to “hotel load” at the back-end of the project shall be considered.
 - c. The Project Risk Management Plan should account for the possibility of having to use incentives at various key times in the project schedule.
 - d. This acknowledgement must also be applied to essential Field Non-Manual (FNM) staff across all disciplines. Retention of skilled FNM engineering staff (design and field) was a significant issue at Vogtle.
- 5. Lack of acknowledgement of complementary labor/FNM categories that are required for performance of defined work evolutions; i.e. surveyors, riggers, operators, QC inspectors, weld NDE inspectors, etc.**
 - a. Recognition of the rigorous design, procurement, construction, and testing requirements for a project performed to “nuclear criteria” (NQA-1, ASME Codes, etc.) should not be underestimated with regard to primary and complementary FNM staff and construction labor first-line supervision (foremen and general foremen). This also applies to design engineers who will have to be available for “real-time” change management as construction progresses.
- 6. Design incomplete in key areas or with insufficient details to allow confident procurement actions.**
 - a. Honesty about the actual state of the design has historically been a challenge. Too much weight is given to the civil/structural portions of the design and not enough given to the final mechanical, electrical, and I&C portions of the overall design. This relates back to a properly balanced EVM system and the associated rules of credit.
 - b. Time spent up front in engineering to finalize designs relevant to heat load calculations and equipment sizing is essential to establishing viability of system layouts and their relationship to adjacent systems. Same for pipe volumetric calculations and cable tray/conduit fill calculations and routing paths, otherwise there will inevitably be growth in commodity size and quantities thus impacting space allocation plans. This also applies to pipe supports with regard to sizing of structural members and subsequent attachment to concrete surfaces and beams.
 - c. Determination of allowable design margins in structural systems and commodity supports should be realistic and based upon static and seismic loading and not multiplied upward by a factor simply “to be better”.

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- 7. Design either “not constructible without field changes” or “constructible but inefficient (i.e. expensive)” with no simple avenue for timely mitigation w/o schedule impact.**
- a. Engineering should be careful to not “over apply” codes and standards driving unnecessary cost and schedule. Engineering specifications need to specify only what is required to meet regulations and should not specify beyond that without considering the impact; i.e. “required to have” versus “good to have”.
 - b. Analysis and maintenance of space allocation in all rooms and corridors is critical, requiring the prioritization of systems, processes, etc. for available building location and footprint. Consideration of installation, maintenance, and replacement for mechanical and electrical components must be performed and verified through use of vendor manuals and construction/operations review where feasible.
 - c. Design of reinforcing steel and structural steel shall consider access for bolted, coupled, and welded connections and post-installation coating applications.
 - d. “Change Paper” management to support construction is critical. One size cannot fit all; consideration of safety related versus non-safety related changes needs to be evaluated in the approval process. The ability to continue construction with interim engineering approval of a proposed change will be dependent upon the experience of the design and field engineering staff and also whether the proposed change of configuration or item will be accessible for rework if the final engineering review or calculation results in a different approach to resolution.
- 8. Poor procurement engineering integration with construction installation schedule and vendor supply chain capabilities.**
- a. Procurement at risk with incomplete or preliminary design needs to be analyzed for necessity and accounted for on the Risk Management Plan and contingency funding.
 - b. “Early” procurement often results in disproportionate storage and maintenance costs and can lead to exceeding the warranty period for the items purchased well ahead of actual need dates.
 - c. The construction sequences, installation schedules, and testing schedules need to be understood by Procurement to ensure that the delivery of components and materials supports the project. Constant and detailed communication between organizations is essential. Owner oversight of this is very important.
- 9. Little recognition of vendor supply chain (NQA-1) deficiencies in quality manufacturing and production capabilities.**
- a. Engineering specifications need to be reviewed to ensure that they clearly state the product requirements and associated quality inspection criteria.
 - b. Vendor oversight by the EPC agency and the Owner cannot be stressed enough.
 - c. Receipt inspection criteria shall be clearly defined in the Engineering specification.
 - d. The EPC and/or Owner should plan to provide guidance to help the vendors achieve NQA-1 quality results and not just penalize the vendor for poor performance. This is upfront cost that will easily pay for itself when the vendor can become self-supporting and deliver the final products that meet quality requirements.

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10. Procurement/warehousing and construction schedules not fully integrated nor adequately developed (delivery and receiving inspection of material/equipment durations with regard to installation schedule).

- a. Similar to item-8 but focusing on the Site management of material delivery to construction forces. Understanding of priorities for delivery, inspection, and transport for “just-in-time delivery” to minimize adjacent laydown staging areas and traffic in the construction areas.

11. Construction installation sequences and subsequent integrated schedules inadequately scoped (not fully labor and/or FNM resource loaded, not equipment loaded (i.e. crane availability, etc.), no work front labor saturation considerations, etc.).

- a. Installation sequences and schedules need to be fully integrated between all disciplines to allow for the logical installation of bulk commodities and equipment. It cannot digress into a “we were here first” mentality. Strong construction management and general supervision is required for this to be effective. Owner oversight can highlight many poor sequences and drive EPC mitigation.
- b. Work front congestion and labor saturation must be analyzed and understood and resultant sequences scheduled to reflect the critical path.
- c. Building access points and availability, transport limitations, crane use planning (a project life cycle “crane & rigging plan” should be developed), overhead work activities, etc. need to be recognized and built into the construction schedule.
- d. Thorough consideration of site infrastructure support needs should not be overlooked. This would include warehouse yards, covered warehouse footage defined by quality level, material laydown and staging areas adjacent to the work fronts, build-out of site roadways to support construction traffic, installation of underground temporary construction and permanent project utilities and rail lines as early in the project as possible, a site drainage plan that accounts for the time-phased progress of construction of the project facilities, parking and transport for construction and FNM workers, entrance/exit gates and turnstiles, radio and wireless repeaters to support construction communications, required environmental controls (silt fencing, dust control, emission limitations, etc.), stadium lighting for backshift activities, etc.
- e. Shift work labor balances need to be carefully scoped to ensure efficiency. Experience indicates that crews assigned to a designated shift should be dedicated to specific work scopes and do not share scope across shifts, which often results in rework between the shifts. This does not apply to testing and commissioning. A backshift multi-discipline construction force dedicated to supporting day-shift forces through general cleanup of the work fronts, staging of materials, relocation of temporary construction power and ventilation, erecting/breaking down scaffolding, cleaning of restrooms/portalets, etc. has proven to be beneficial.

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12. Generation of concrete mix designs prior to the start of permanent plant construction.

- a. Development of the appropriate concrete mix designs can take up to twelve months of testing, especially for unique mixes such as for self-consolidate concrete (SCC).
- b. Mix designs should be developed for multiple sizes of aggregates and potentially from several fly-ash and sand sources to account for flowability, set/cure rates, and ready availability for delivery in large quantities.
- c. Mix designs should be developed in multiple strength ranges to account for placements with unforeseen borderline design margins where a higher strength would potentially be needed to ensure compliance with design criteria.
- d. For placements containing high congestion of reinforcing steel and embedded items, the use of SCC is recommended to minimize consolidation concerns. This has proven to be a key element of concrete progress at the referenced commercial nuclear projects.
- e. The use of concrete placement situational mock-ups is recommended for field testing of mix designs, equipment, and personnel.
- f. Concrete placement plans should be developed well in advance of a scheduled placement and walk-throughs with the personnel who will be performing the placement should be held. The plans will include contingencies for placement equipment failure, batch plant/ice plant failure, changing weather conditions, form failures, consolidation issues, etc.
- g. If mass concrete placements are planned in the summer months, the ability to use on-site nitrogen sparging to reduce fresh concrete temperatures is recommended.
- h. Training of personnel in all phases of concrete production and placement should be emphasized. This includes batching, mixer truck delivery at the work front, Field Engineering and Quality Control documentation and approval of the delivered mix, placement out of the chute, pumped placement, bucket placement, proper vibration technique for placed concrete, finishing of placed concrete, application of curing compounds, and curing methodologies.
- i. The concrete batch plant footprint must be sized to support the largest placements and to support maximum required production rates. Water delivery interruption, ice plant failure, and electrical power supply contingencies should be proceduralized.

13. Lack of early tracking for schedule adherence of key milestones (also of key predecessor activities).

- a. Schedule adherence is an essential measurable indicator of work performance. Allowing adherence to the schedule to drift without firm justification is “contagious” and leads to bad habits. Owner oversight can demand this justification and help keep the EPC on track.
- b. Independent oversight/assessment personnel need to be in the field and knowledgeable of construction techniques and processes in order to be able to provide “early warning” of imminent schedule slippage.
- c. Item-b applies equally to design engineering output.

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14. Engineering, procurement, quality, and construction processes and procedures not fully developed for a large scale and time critical project.

- a. Processes and procedures need to be vetted early in the life-cycle of the project and adhered to throughout. Multiple revisions are to be expected and are actually an indicator of learning through experience what works best to accomplish the particular scope described in the procedure.
- b. Over-proceduralizing is a handicap to the field forces if there is no return benefit.

15. Lack of recognition of required FNM staffing levels and the necessary levels of expertise required to reach performance objectives.

a.

(b) (5)



- d. The sensible goal is to “keep craft working”, therefore, a balanced FNM work force is essential for this to occur. Saving on FNM headcount for perception purposes will hurt the project with regard to cost and schedule.
- e. Owner oversight can recognize where FNM staff deficiencies exist and where they are redundant. The key is that the FNM staff has to be active in the field working with construction to mitigate potential work stoppages.

16. Lack of senior and mid-level management experience and hands-on leadership.

- a. Management at all levels needs to be engaged with their departmental counterparts (Engineering with Construction with Quality, etc.) and their presence needs to be seen in the field. This includes at early morning POD's, shift turnover, etc. They need to be a visible presence “walking the decks”. They need to know their staff and capabilities.

17. Cost Account Management failures.

- a. Cost Account Managers (CAM's) need to be identified for all construction, engineering, procurement, material management, and quality scopes from the beginning of the project.
- b. CAM's need to “own” staffing levels within the bounds of the project cost estimate and have the ability to change levels with firm justification and executive approval. The project has to demonstrate flexibility in managing manpower in relation to progress and emergent issues.
- c. The CAM's need to have sufficient project controls staff embedded within their Departments to inform them of current cost and schedule status and future projections.

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18. Establishment of a Project Risk Management Plan.

- a. A Project Risk Management Plan should be generated prior to the start of construction and account for all aspects of the project; i.e. engineering, procurement, construction, commissioning, etc.
- b. Contingency funds should be based upon the Risk Management Plan and the payout of these funds should be rigorously tracked. Disbursement of these funds should be the responsibility of the Owner unless the EPC firm(s) has an appropriate margin built into the contract mechanism, see item-c below.
- c. Management Reserve should be the source of immediate funds for emergent issues that have to be addressed in a real-time process. These reserve funds are managed by the EPC firm(s) through an established allocation and approval process with the Owner.

19. Lack of follow-through with regard to problem and issue mitigation..... ACCOUNTABILITY at ALL LEVELS!!!!

- a. Accountability, accountability, accountability.

20. Lack of experienced oversight personnel and integration of oversight personnel into the EPC forces by the Project Owner (at the commercial nuclear power plants this was Southern Nuclear Company and SCANA).

- a. With regard to the commercial nuclear power plant projects, the Owner oversight personnel typically had operations experience and through no fault of their own were understandably overwhelmed during construction. There is no substitute for having previously performed and managed major project construction in order to be able to observe and assess the actual practice of construction in many cases. The sheer quantity of concurrent work activities can overwhelm someone who does not have the depth of knowledge to delineate the critical events.

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21. There are three areas of accountability that have been the cause of much cost and schedule pain within the commercial nuclear power industry that also apply to DOE projects, namely –

a. Configuration Management and Control

- i. Management of Project documentation (design engineering, procurement-vendor records, construction records, weld records, quality records, testing records, construction work packages, etc.)

b. Material Control

- i. Tracking of material delivery and receipt by Material Management and Construction, segregation of materials by material type and quality level, transfer of heat numbers when sizing materials, inappropriate use of bulk commodities, maintenance of internal and external cleanliness criteria, early establishment of a preventive maintenance program, etc.

c. Weld Control

- i. Control and issue of weld filler metals, witnessing of weld process Hold Points, completion of weld documentation, weld repairs, welder testing, etc.

These three areas need to be strictly supervised by the Contractor and assessed/audited on a regular basis by the Owner. Lack of mitigation of issues in these areas is ultimately painful and costly to the Project.

The above is a simple roster of items for consideration, each item would of course have a cascade of associated details that could be expounded upon. The Vogtle and VC Summer nuclear plant projects could be considered poster children of how not to enter the construction phase of a project without having all predecessor elements (engineering, procurement, quality, etc.) thoroughly vetted for status and accuracy. All the above are items that need to be vetted and tracked throughout CD-1 and into construction/startup on any future major project at SRS or other Department of Energy site.