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SMR Deployment & Learning from the Past & Present

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James Carter, JECA Consulting, LLC
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Small modular reactor deployment: Learning from the past and the present



James Carter

JECA Consulting, LLC, United States

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ABSTRACT

The success of SMR technology will depend on the initial projects' ability to demonstrate economical construction without falling victim to the large cost overruns of nuclear projects both past and present. The remarkable tool and process evolution of recent years suggests a very favorable outlook for building SMRs on time and within budget. However, challenges remain, as evidenced by difficulties with current nuclear construction projects.

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1. Introduction

Global net generation from nuclear power is projected to increase by 91% between 2012 and 2040. However U.S. nuclear generation is expected to increase by only 8%.

Nuclear power emits no greenhouse gas or other atmospheric pollutants.

The U.S. once led the world in nuclear power generation. However, new nuclear facility deployment in the U.S. has stalled. Seven operating nuclear plants are scheduled to close by 2025, due primarily to market rules. The plants that are closing represent over 32 million metric tons of carbon emission increases per year (the equivalent of 6.9 million cars in the U.S.).

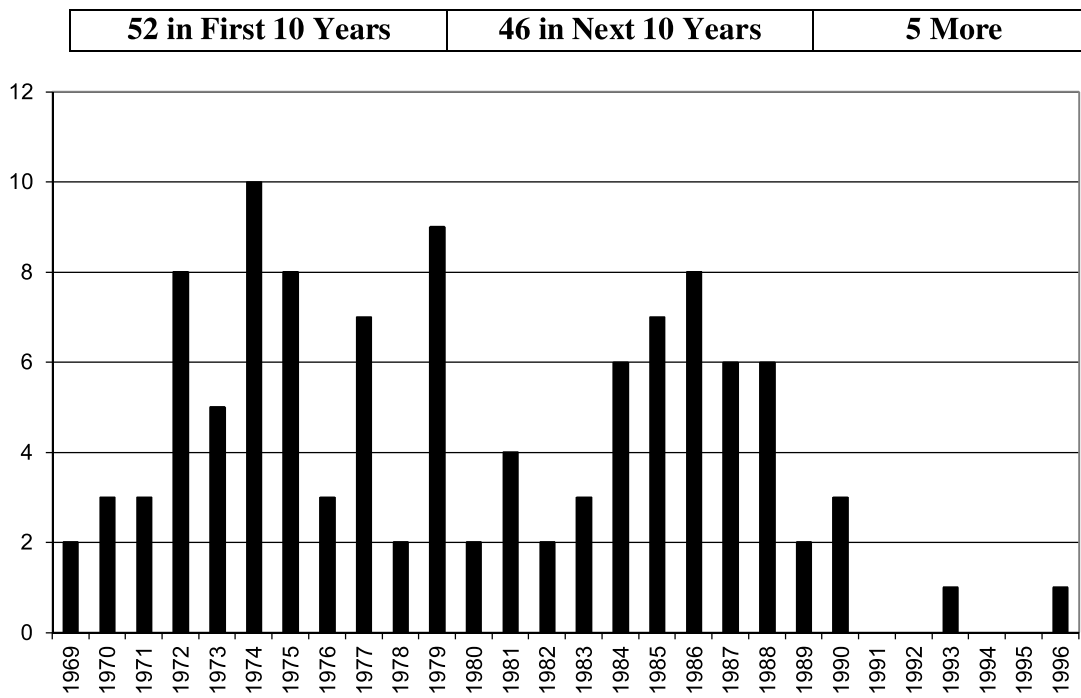
Despite all their benefits, solar and wind generation can't be expected to supply the growing demand for electricity without other sources such as nuclear. Some herald Small Modular Reactor (SMR) technology as an attractive driver for deploying safer, cost-effective and financeable nuclear plants in the U.S. and abroad. The success of SMR commercialization and deployment will be significantly measured by the early deployments. Consider, however, that new nuclear build projects have a reputation for extended schedules and overrun budgets.

This paper will assess the outlook and challenges facing (SMR) deployment. It will draw from historic and recent research; and near fifty years of personal first-hand involvement with the nuclear power industry, including current experience with state-of-the-art best practices.

E-mail address: JC@JECAconsulting.com (J. Carter).

2. Background

U.S. Nuclear plants Placed in Service during the 70s and 80s



The last domestic nuclear build period spanned 25 years. During that period, over 100 units were placed in commercial operation. **Fifty-two were put online in the first 10 years.** Consider a point in the late 60s and compare it to our present situation. In the 60s, we essentially started with nothing! Only a cloudy blank sheet of paper, some early prototypes, and some ideas! Here's a look back at the situation during early stages of the U.S. commercial nuclear power industry:

1. No nuclear component manufacturing infrastructure.
2. No prior commercial nuclear experience.
3. No proven commercial design (experimental and naval reactors, yes; but nothing of the commercial scale and design.). Without prior proven designs, numerous problems or concerns raised at one plant required evaluation and changes on others in a cascading manner.
4. Drawings were pencil on mylar and were manually reproduced in wet-solution reprographic machines.
5. Codes, Standards and regulatory mandates were new and evolving. Changes impacted efforts to design and build within budget and schedule.
6. Document review was conducted by manually developing notes or annotating on hard copies.
7. Composite drawing and physical models were manually prepared to detect interferences in the design layout.
8. An industry that was familiar with building fossil steam plants, but not the complex nuclear plants with the rigorous and newly developed (developing) quality standards.
9. A well-intended two phase licensing process that prompted numerous design changes.
10. During this period the U.S. experienced double digit inflation, double digit interest rates and three economic recessions!!!
11. Word processing was by typewriters with correction tape and white-out.
12. Schedules were hand-drawn logic sheets with main frame data reports that did not logically reflect reality in the field.
13. Engineers relied on slide rules.
14. Computerized engineering tools were just coming into use, requiring manually-punched key card decks and main frame computers. Programs had to be queued in the mainframe schedule and took time before output was available. Often programs had to be re-run as input errors were detected and corrected.
15. Project management processes were limited and project leadership was often substandard.
16. A proclamation that nuclear power offered electricity "too cheap to meter" and a population expecting that result.

Notwithstanding the above challenges, these very complex plants actually worked. They worked well and continue to work very well, despite the challenges and rigorous demands for operational excellence. Many people did their jobs and they did them well!

Today's design, construction and project management tools and processes are much more advanced than in the last nuclear build period.

1. The industry has years of experience successfully operating and maintaining nuclear plants. This has contributed significant Operating Experience to inform new designs and theoretically reduce design changes as new issues are reduced.

2. The two step licensing regulation has been replaced by a single Combined Construction and Operating License (COL).
3. Mature quality assurance and quality control processes are in place.
4. The industry has accepted standard designs, which allow:
 - a Customization only to address site-specific matters – significantly reducing engineering and design costs which can be spread over numerous plants.
5. Standardized and efficient procurement of components and materials.
6. Standardized manufacturing of components.
7. Standardized procurement, construction, commissioning, operations, and maintenance practices, permitting continuous improvement based on lessons learned.
8. Reduced uncertainty in estimates and schedules.
 - The adopting of modular, “open-top” construction methods.
 - The advance of computer systems allowing for significant improvements in engineering, design, estimating, scheduling, project management, and project status reporting.
 - Advanced risk management tools and techniques.
 - And others.

Current new large nuclear projects under construction in the U.S. were expected to experience a streamlined construction period based on innovative modular construction techniques, standard designs, and advanced project management, design, and construction tools and techniques. However, the current plants have experienced some of the problems that historically plagued the industry. Indeed, there are some growing pains associated with a new design, new manufacturing, and new NRC regulatory regimen. However, problems of the past seem to persist.

The lessons learned from the past and from current experience can fill volumes. SMR deployment must not fail. The tools are available and the design is presumably optimized. However SMR stakeholders cannot fall into the “Business as Usual” trap. Confidence in existing processes, procedures and personnel must not undermine the need for careful assessment and challenge. Too much is at stake. Even with “tier one” contractors and (presumed) optimized policies, procedures, processes and personnel, effective execution is not assured.

As SMR deployment gets underway, the significant opportunity and risks must be kept in perspective. SMRs stakeholders are doing more than pursuing commercial success and more than reconstituting an industry. They’re taking on a significant responsibility. One may even consider the responsibility to be more of an obligation!!! . . . a very serious obligation to advance . . .

- . . . a technology the country and the world needs.
- . . . a technology that has a zero carbon footprint.
- . . . a technology that uses a plentiful fuel that can be recycled.
- . . . a technology that does not rely on fuel from cartels and countries that oppose our way of life.

Without sounding too sensational, SMRs can truly make a huge difference in the world. However, the outlook is uncertain because the first several plants can make or break the technology commercialization. Commercial failure will doom technical superiority.

This paper is not a sanitized version of history. It focuses on shortcomings, challenges and lessons to be learned. The opinions and the opinions of others presented herein may not reflect the experience of all who participated in the past or recent programs. There may be different points of view. Frankly however, there is likely more agreement than disagreement. Consideration or rejection of the content is the responsibility of key stakeholders. When one compares the tools of today with those of the past, how can SMR deployment fail?

A number of the factors affecting the earlier nuclear build have been resolved through the passing of time, the evolution of technology and changes in the requirements for licensing and building nuclear plants. Those, such as the two phase licensing process, will not be addressed here. It’s remarkable however that many of the earlier “unforced errors” continue to haunt the industry.

3. The past situation and suggestions for SMR deployment

Observations and lessons learned applicable to SMR deployment can be grouped into four categories;

1. Planning and Control
 - a Scoping
 - b Estimating and Scheduling
 - c Risk Management and Contingency
 - d Reporting
 - e Commissioning
2. Engineering & Procurement
3. Contracting
 - a Contract Provisions
 - b Contract Management
4. Organization and Culture
 - a People
 - b Leadership
 - c Structure
 - d Owner Involvement
 - e Communication
 - f Accountability

3.1. Planning and control

3.1.1. Scoping

The Past Situation: In addition to scope definition deficiency due to incomplete design, scope control was often lost when changes weren’t properly added to the scope. This of course contributed to inaccuracies in the budgets and schedules described below. In addition, responsibilities for executing scope items were often obscured by inadequate programmatic methods for managing scope.

Lack of clear definition of responsibility for performing base scope and authorized changes often led work not being performed and/or not planned. In some instances, ripping out completed work was necessary to install a change, causing cascading schedule and cost impacts. Formal change authorizations were necessary to accommodate contractual requirements. Too frequently, these change orders were executed and approved for expediency without effective challenge and vetting . . . more cost and schedule impacts resulted.

Suggestions: A detailed and accurate scope definition based on a comprehensive requirements assessment; engineering and design maturity; and procurement and construction planning is not enough. There is never certainty until the project is completed. Therefore a well-planned change management program is important. Before implementing a CM program, however, an accurate cost and schedule baseline must be in place. Without accurate baselines, processing changes can become overwhelming and subject to abuse by “after the fact” or inappropriate approval in order to keep the work moving. It’s not uncommon to see situations where there is not enough time to process scope

changes . . . too busy to do the paperwork, when the physical work is backlogged!

Change Management Programs vary, but should be simple to execute, must address causation, causal responsibility and funding source; budget and schedule impact; and responsibility for execution. The programs should provide for updating databases such as those dealing with schedule and cost control. Approval authority should be as low in the organization as reasonable.

It's important to note that contract changes may be necessary, so contract management and supply chain organizations need to interface. Initial contract language should have provisions for dealing with in process changes. If a solid change management program is in place at the time of contract negotiations, much later effort can be avoided.

3.1.2. Estimating and scheduling

The Past Situation: Inaccurate schedules and budgets begat inaccurate and ineffective plans, which in turn contributed to project cost overruns and schedule delays. Incomplete designs created high uncertainty in estimates and schedules. Driven perhaps, by the desire to obtain project authorization and get started or to win a contract award, initial estimates and schedules tended to be overly optimistic. Estimates and schedules were not uniform as various input resources had different degrees of expertise, rigor and optimism. Reviews and vetting were often perfunctory, sometimes performed by "interested parties" instead of independent experts. Labor productivity rate data was immature, non-existent or was based on non-nuclear experience. There was very little risk and uncertainty analysis, if any. The resultant plans often had limited value in managing a project and were difficult to accept by those responsible for performing the work. Complete schedule integration was lacking. Schedules were frequently organization or discipline based, within silos that challenged effective interfacing.

Construction builds by "Area", so they scheduled by area. Structures and large components came first, then smaller equipment was installed . . . still by "Area". This created interface problems because engineering designs by systems, which frequently involve many areas. Commissioning proceeds with components first, then subsystems, systems, and integrated operations. Construction dominance in the scheduling process resulted in priority for construction requirements; but effective front end and back end interfacing was weak. Often mere "allowances" for critical schedule elements were provided.

The scheduling and estimating tools at the time were incapable of frequent modification to sustain a valid plan. As engineering and design matured, costs escalated and schedules slipped. Contractor change orders became extensive and often were aggregated into one mega-budget increase request and hastily approved. Stakeholder confidence waned and "righting the ship" became increasingly difficult because of the volume and significance of changes and the lack of effective primary project management tools. Often new management was brought in to aggressively pilot the ship to the pier.

Suggestions: The value of a fully integrated total project schedule cannot be overstated. It is the backbone of project management. Schedule development and integration should extend from the early concept stage through detailed engineering, procurement, construction, commissioning and integrated plant startup. Early integrated schedules may be imperfect, but they are valuable in establishing priorities for engineering and procurement activities. Engineering teams must know when their deliverables are required to support successor activities such as other engineering disciplines, procurement solicitations and orders, construction work packages, test program procedures, O&M training and many other activities.

Enlightened mega-projects today exercise restraint in finalizing and formalizing budgets and schedules until the project scope is well defined and engineering is virtually complete to allow accurate construction and procurement scheduling and estimating.

The Association for the Advancement of Cost Engineering (AACE) has developed useful guidelines for identifying "expected" estimate and schedule accuracy ranges based on the maturity level of project definition deliverables. For example, an AACE Class 1 estimate produces an expected accuracy to be between -3% and +10% on the low side and -3%+15% on the high side. Class 1 involves 65%–100% maturity level for project definition deliverables.

3.1.3. Risk management and contingency

The Past Situation: During the 70s and 80s, programmatic risk identification and mitigation efforts were virtually non-existent. Design risks affecting plant operation and safety were addressed in great detail as one would expect for a nuclear plant. Project managers, however, dealt with project risks as they arose and suffered unanticipated schedule and cost impacts. "Murphy's Law"¹; ruled the risk landscape. There were no preemptive mitigation efforts and a reactive corrective response was triggered when the risk was realized, creating solutions developed on the spot that often carried painful schedule and cost impacts.

Contingency for estimates and schedules was usually informally embedded in estimate line items and schedule durations. This varied with the individual sources and was not visible for review and vetting. Occasionally, deterministic and somewhat arbitrary values for contingency were applied to obviously uncertain budget and schedule items or to the overall base. However, little, if any effort was made to reduce the contingency. *It was there and it would be used!*

Suggestions: In the past, three factors were considered the essential focus areas for mega project management: 1.) Scope, 2.) Schedule and 3.) Budget. With the development and acceptance of new processes and tools, a fourth leg for Risk Management has been added to the stool.

In general, state-of-the-art risk management processes involve a comprehensive effort to identify "discrete risks" to project success. These are defined by describing a.) the event, b.) the cause, and c.) the effect or impact. The probability of risk occurrence is established by experience. Values for cost and schedule impacts are estimated within a set of prescribed ranges. Based on these inputs, discrete risks can be qualitatively scored and priority for mitigation strategies can be focused on those with high scores.

To create contingency, more quantification is necessary. Three point values reflecting low, mid and high likelihood can be applied to each risk cost and schedule impact. A Monte Carlo analysis is then performed to establish contingency with the desired level of confidence. Similar ranging and Monte Carlo analysis is done for elements of the estimate. Combined, an aggregate value of project contingency can be established.

3.1.4. Reporting

The Past Situation: Early nuclear projects had limited tools for effective updating and progress reporting. Manual methods and card decks did not support rigorous earned value analysis and reporting. Usually costs were reported by a roll-up of period invoices and augmented perhaps with monetized labor time

¹ "Things will go wrong in any given situation, if you give them a chance."

charges. Those figures were compared with budgets to ascertain percent spent. Project schedules, rudimentary as they were by today's standards, could be "stated" by estimating the percent complete of the activities, albeit on a relatively high level-2 basis. Given the time and labor to obtain and then process such input, schedule status reports were outdated by the time they were issued and subject to considerable uncertainty. While these schedule reports were of general use; they lacked credibility and were often discarded in favor of subjective reports based on observation and self-generated lists. Progress was often measured by milestone achievement. As projects progressed, and testing and turnover activities appeared on the horizon, punch lists became the default schedule management tool. Budget tracking remained subjective. Little was available to compare cost to actual work accomplished and the budget for that work.

There was usually a high reluctance to convey bad news. Contractors worked to correct problems without reporting them, in hopes that additional effort would cause resolution without fanfare. This occasionally worked, but when it did not, optimum solutions were usually unavailable due to the passing of time.

Technical quality was subject to independent inspection and verification. Therefore it rarely suffered the information suppression associated with schedule problems.

Suggestions: Modern tools and techniques facilitate effective schedule and budget development and tracking. However, they are only as good as the input. Estimate and schedule development must go hand in hand. SMR stakeholders should devote significant attention to developing the critical initial project schedules and budgets.

For SMRs, the benefits of standardization can be significant when effectively applied to schedules and budgets. SMR developers would be well served to monitor actual schedule and budget performance on a project and update the standard schedule and budget package based on field actuals when appropriate.

3.1.5. Commissioning

Situation: In the past, test program activities were rarely scheduled in initial plans by knowledgeable commissioning professionals, who usually arrived on a project very late in the game. There was little precedence for test program schedules and almost every test program involved different approaches. Standardization was totally absent. Commissioning schedules created by unqualified professionals were essentially place holders with surmised bulk allowances for testing and turnover. There were no detailed interface ties between construction and test program activities. Absent that integration construction sequencing was not established to accommodate test program requirements without significant alteration and redirection.

These required significant changes to schedule and budget when informed revisions were incorporated.

Suggestions: Commissioning is critical path activity and it is not an insignificant duration. Construction completion activities must be detailed and properly interfaced with detailed test program activities to achieve a logical and optimum approach to fuel load. This is a classic "square peg and round hole" situation. The interface between construction and testing is a difficult one. After years of operating in field construction conditions, the project must shift to test program conditions with live switchgear and pressurized heated pipes; and ultimately to operating nuclear plant conditions. Effectively preparing for this challenge must occur during the early project planning stages.

SMR developers would be well served to take advantage of the standard design concept and establish a standard test program that deals with all aspects of commissioning from construction tests (such as pressure testing) to preoperational and integrated systems testing. Technical test procedures and programmatic matters such

as provisions for turnover boundaries and turnover package requirements should also be addressed. Subsequent SMR units can benefit from lessons learned on previous units and the standard test program package can be revised to benefit from prior experience. Customers who prefer to do things their own way will not realize full benefit of standardization.

3.2. Engineering and procurement

3.2.1. Build before design completion

The Past Situation: Following the lead of earlier fossil plants and many industrial facilities, utilities in the 70s tried to build the complex nuclear facilities with somewhat of a "design as you go" approach, perhaps hoping to achieve schedule compression, but actually forcing schedule delays and cost increases, precluding effective construction planning, and rendering budgets and schedules inherently inaccurate. Public commercial commitments also became subject to significant criticism as costs increased. The notion of completing design before building is not new, but we still see it on large projects across industries.

Suggestions: It stands to reason that the more complete design and procurement activities are, the stronger the estimate and schedule. Nonetheless, owners and contractors continue to publish estimates and embark on construction with critical aspects of design and procurement incomplete. Section 3.1.2 above addresses the categories advanced by the Association for the Advancement of Cost Engineering (AACE) to categorize the estimate accuracy consistent with the maturity of project deliverables. These categories serve as guides to band the estimate accuracy and to assign ranges to elements of the estimate in developing contingency. SMR developers should consider achieving at least Class 2 Estimates (including contingency) with the understanding of the associated accuracy.

3.2.2. Custom designs

The Past Situation: The designs of twentieth century US nuclear plants can be classified by identifying the vendors that provided the Nuclear Steam Supply System (NSSS). However, with a very few exceptions, the NSSS generally consisted only of equipment supply and design specifications for safety related systems. The remaining design, physical layout and associated procurements were performed by others. Structures, balance of plant systems, and auxiliary/support systems were usually designed by the prime contractor with significant owner preference input. Given the relative long duration of these projects, personnel turnover often changed the preferred configuration or equipment selection. Owner preference and regulator initiated changes occurred throughout project. Often, early engineering activities had little appreciation for the requirements of downstream organizations. As a result, the lack of early input from experienced operations, maintenance, and test personnel prompted costly mid project changes. Occasionally, the dominant party (squeaky wheel) in arguing for design preferences ruled the day, regardless of the cost/benefit.

Suggestions: Today, SMR designs are standardized and the industry recognizes and accepts standardization. Nothing is guaranteed, however. Changes will be necessary. Changes will be minimized to the extent SMR designers have considered owner/operator, supplier, construction and commissioning input. The parties may have legitimate positions, but the cost/benefit of each must be assessed, together with the typical balancing of capital cost vs. (future) O&M costs. The decision authority may be the party holding the purse strings. However, SMR developers must strongly resist unnecessary changes in order to preserve the standard design model. Consideration of all stakeholder interests must be accomplished during the early standard design process. If

not, the risk and impact of changes will increase. Changes after project initiation are more impacting than changes in the pre-project period. Therefore, SMR designers must be extremely rigorous in all aspect of the design. Engineers with limited construction, operations, maintenance and commissioning experience must be supported by experienced experts.

As the design authority, intellectual property holder, and primary stakeholder in future deployments, the SMR vendor should design against change, be rigorous in resisting change, and limit changes to those that are absolutely necessary. Such change control should be addressed in appropriate contracts.

3.2.3. Procurement

The Past Situation: In the past, supply chain activities were impacted on the front end by the timeliness of engineering and design deliverables necessary for specifying the nature and quantities of material and components. On the back end, supply chain must know when site delivery is required to support construction and avoid excess site warehousing. This clearly challenges the procurement process.

In addition to delivery of permanent plant equipment, procurement activities must ensure that vendors provide supporting material and services such as operating and maintenance instructions, spare parts recommendations and technical support for installation, commissioning, and operation as appropriate. Past practices were deficient in this support area. However, current operating plants routinely addressing these issues in procurements.

Suggestions: The value of a fully integrated total project schedule cannot be overstated. As addressed above, engineering teams must know when their deliverables are required to support successor activities such as procurement solicitations and orders. Schedule support is not the only consideration. Engineering documents must be consistent with procurement requirements. Established Architect Engineering firms have such interface requirements and technical procurement specification processes in place. However, SMR stakeholders should ensure that such processes and procedures are current and reflect the needs of all parties, including the commissioning and operations teams.

3.3. Contracting

3.3.1. Contract provisions

The Past Situation: With the exception of several lump sum turnkey contracts early in the commercial nuclear power industry, EPC contracts (i.e. those for engineering, procurement, and construction services) were primarily based on reimbursement for time and materials. With limited stake in the outcome, contractors had no commercial incentive or disincentive in the project's success. Vague contract language, often led to disputes. Weak contract issues were related to: a.) responsibilities and authorities, especially for turnover and commissioning, b.) scope, schedule, and budget control, c.) change control, d.) reporting requirements, e.) problem identification and resolution, f.) milestone definition and achievement, g.) contractor management, h.) prerequisite planning, and many others. Some may argue that details on such matters are inappropriate for contract. However, lack of contract mandated processes with defined minimum requirements and approvals often led to weak processes favoring the contractor or incurred avoidable cost for effecting contract changes.

Suggestions: Separate contracts can be established dealing with phases of a project. For instance, before a large EPC contract for the plant is awarded, a planning phase agreement can be put in place for developing estimates and schedules and preparing for execution. Such a planning phase would inform the development

of an execution phase contract. The carrot of obtaining the execution phase work would be performance incentive for the planning phase contractor. Obviously, experience gained by the planning phase contractor would be valuable for executing the work and the performance phase contractor would likely be most suited. However retaining the option to select a different contractor would be advisable.

Based on the planning phase, hybrid execution contracts could be developed. Such hybrids vary; but may involve three approaches:

- Fixed Price – where the scope is well defined, the parties could agree on fixed price terms whereby the contractor agrees to perform the well-defined scope for a set price.
- Time and Materials – where the contractor is reimbursed for allowed labor and expenses with provisions for overhead and profit.
- Target Price – where services are reimbursed on a time and material basis with a threshold, below which the contractor receives incentive and above which the contractor does not and may be penalized.

There are numerous variations and details associated with these hybrids, but they have gained favor in recent mega-project contracts. Experts experienced in hybrid contracts must be involved . . . not just attorneys, but also individuals with experience in similar contract performance on a nuclear project. Such experts should be involved regardless of the hybrid nature.

A well informed contract development team can address issues based on direct experience and can ensure that technical and commercial contract language focuses on minimizing problems during contract performance. Such support is well worth the cost.

3.3.2. Contract management

The Past Situation: Contract management was often considered an administrative function, focused on invoice review and accounts payable. Contract administrators were often mid-level quasi-clerical personnel with limited authority and marginal responsibility for oversight of contract compliance (contrast with the enormous oversight of technical quality control).

Often, project teams were too busy to deal with the responsibility for budget or schedule changes and were not well versed in contract requirements. They focused on getting the physical work accomplished. Project managers often were swamped with their duty to manage contractors and resolve problems. They had little time to focus directly on contract management, unless a significant issue arose.

The result was poor documentation of the rationale for authorizing specific changes, causation and responsibility. Such documenting of effective contract management becomes important in post-project proceedings, such as regulator prudence reviews that assess owner's effectiveness in managing contracts.

Suggestions: Contract management responsibilities should be well defined and unequivocal. The function should not be back seated in administrative purgatory, but should be represented at the project management table. If project managers have contract administration responsibilities, care should be taken to avoid distracting PMs from their primary tactical and strategic duties.

In the heat of battle, properly documenting changes must not be lost. Contemporaneous documentation of events is much more probative in hearings than retrospective reconstruction of facts. Whether this responsibility falls under a contract management team, a change management team or elsewhere is subject to discussion and decision by management.

3.4. Organization and culture

3.4.1. People

The Past Situation: Consider the number of nuclear power plants under development and construction during the 70s and 80s and consider that, during the early 70s, there were very few individuals with experience designing and building a nuclear plant. Resources were drawn from fossil projects, shipyards, navy nuclear program, aerospace, and other industries. New graduates and apprentice workers with little or no experience were placed in positions of responsibility. Often with limited supervision until it was time to review or check the work. There was very limited training. What training there was focused on safety and quality control programs – little on technical, project integration, schedule, budget or commercial matters. The high demand/low supply of resources forced acceptance of sub-optimized performance, which was better than no performance . . . but it extracted a toll in processing the acceptance of work products. Management and supervisory personnel often were marginally qualified, sometimes exacerbating problems. Good engineers were presumed to be good managers; which wasn't always the case. Management and supervision, often overwhelmed by day-to-day challenges, couldn't do on-the-job training or personnel mentoring. These issues did not compromise plant safety or technical quality because of the rigorous technical quality controls, inspections, and tests in place; but they did contribute somewhat to cost overruns and schedule delays.

Suggestions: The right people, in the proper positions are a significant factor in the success of any project. The available experienced resources in the market today cannot support the activity that was underway during the earlier new build period. And the supply of capable and experienced professionals and construction workers is an issue that SMR deployment stakeholders need to seriously address. All SMR stakeholders must seriously devote time building a team of highly capable individuals. Individuals with experience during the 70s and 80s boom are rare in the market place, but they are valuable. So it may be necessary to supplement staff with top quality advisors who have large capital project management or oversight experience.

Building trades personnel are critical to project success. While there are some "travelers", the largest compliment of craftsmen must come from "local" sources. Training of all project personnel is critical and cannot succeed as an afterthought. This is particularly true where certifications are required, such as for welders. Plans for staffing and training cannot be developed too soon. Executing the plan may be difficult and will take time.

3.4.2. Leadership

The Past Situation: Some projects in the 70s and 80s benefited from good leadership. Many did not. The nuclear new build organizations were not unlike most past (and current) organizations. There was a range of organization managers . . . some who proved to be effective leaders others who were horrible leaders. Usually the project results reflected the leadership skills in the team.

Suggestions: Leadership is the most important factor in achieving successful SMR deployment. Rather than provide a treatise on leadership, we will stipulate that senior members of a project team strongly influence the behavior of all parties. Leaders should be involved as early as possible to set the tone and establish the culture that will drive project success. Many will assert that good leaders are difficult to find and the leaders are born not made. Both notions are myths. If the stakeholder wants strong leadership, it can be found and developed. Don't pass on this!

3.4.3. Structure

Situation: Some organizations were designed around the available people rather than on the functional needs of the project. Too many (or maybe too few) levels or too wide a span of responsibility often resulted. Many organizations were well designed, but some involved silos which inhibited coordination between groups. This was evident between corporate entities such as owner – engineer – constructor – subcontractors. Quality Control organizations, while necessarily independent, occasionally were adversarial, contributing to delays and morale issues. Interface issues arose within corporate groups: engineering (Mechanical vs. Electrical vs. I&C); construction (bulk build vs. small components, area vs. system, piping vs electrical).

One of the most noteworthy interface issues was between engineering and construction. Disputes occasionally arose regarding constructability of the proffered design. (How do they expect us to build that?). Plant staff was part of a different organization and resisted turnover of systems due too very minor and often cosmetic issues (e.g. paint on a gauge face).

A certain amount of protectionism existed where organizations would conceal internal problems that were important to the overall project.

Suggestions: There is an old saying that: "Organizations are perfectly designed for the results they get". All parties on a project have an interest in optimizing the organization. Considering the impact of organization structure, SMR stakeholders should weigh the benefit of professional organization design consultants to advise on the pros and cons of structure alternatives. It makes perfect sense for such a review to focus on the integrated project organization and encompass all involved organizations, rather than just one group.

An important aspect of SMR project organization design is the decision authority. There will always be differences of opinion, but they should not result in impasse that affects project success. Such authority cannot be so far removed that it's difficult to obtain. A clear path to the decision maker must be visible and available to all and there should be no reluctance to transverse the path.

3.4.4. Owner involvement

The Past Situation: Some owners trusted and relied on contractors as the deemed experts. The prevailing position was: "Let the contractors do their jobs, don't interfere". That extreme approach rarely worked. Many owners got involved after a problem became serious. Contractors were reluctant to involve owners in problems that might reflect negatively on their performance. Under-qualified or uncooperative utility teams fueled that contractor attitude. Weak executive involvement and support by all parties until crisis also worked to the detriment of the project.

Suggestions: A Congressional Review by the Nuclear Regulatory Commission² reported that:

"The root cause for the major quality related problems in design and construction was the failure or inability of some utility management to effectively implement a management system that ensured adequate control over all aspects of the project. These management shortcomings arose in part from inadequate nuclear design and construction experience on the part of one or more key participants in the nuclear construction project: the owner utility, architect-engineer, nuclear steam supply system manufacturer, or the constructor, and the assumption by some participants of a project role that was not commensurate with their level of experience."

² NUREG 1055 U.S. Nuclear Regulatory Commission Report to Congress "Improving Quality and the Assurance of Quality in the Design and Construction of Nuclear Power Plants."

Although the NUREG document addressed technical quality, its observations translate well to the commercial aspects of new SMR deployment. Stakeholders in new SMR deployment would be well served by reviewing and addressing the issues addressed in that NRC report.

3.4.5. Communication

The Past Situation: In addition to silo structure issues, communications on earlier nuclear projects were weak. Management teams tolerated silence and did not encourage problem identification or even constructive innovative ideas. Goals and objectives were not uniform across all groups. In most cases they were never articulated at all.

There was no “one project one team” mentality. There were no effective well-defined communication processes. Dead messenger syndrome was prevalent where individuals were reluctant to raise concerns.

In many cases, ineffective management/leadership perpetuated these issues.

Suggestions: Today’s nuclear plants have a formal program for stimulating the identification of problems related to plant safety. SMR stakeholders should consider similar programs for project performance and commercial matters, as well as technical quality issues. An independent confidential ombudsman may facilitate such communication. However, strong communicative leadership stimulating an open win-win culture would be strongly preferred.

The Construction Industry Institute (CII) has developed guidelines³ for establishing mutual goals among all project parties. SMR stakeholders should consider whether all or some of these guidelines can apply to their projects. The CII arrangement requires the appropriate culture and senior personnel personality and commitment to work effectively.

3.4.6. Accountability

The Past Situation: Nuclear projects of the 70s and 80s suffered from a tolerance for mediocrity that continues to dominate many businesses and projects today. Lack of standards and metrics for group or individual performance precluded fair accountability practices. Scarce resources forced the acceptance of subpar performance. Cultural timidity and reluctant management often didn’t act until extremis situations.

Suggestions: Large capital projects are not social clubs. They are business enterprises with significant financial exposure. Expectations must be clearly defined and all work groups and personnel must understand the individual expectations and be held accountable for achieving those objectives. Managers must not operate with a short fuse, but must do what is necessary to ensure

performance standards are achieved. Clearly, disciplinary action in today’s world requires compliance with various legal mandates and corporate policies and cannot be ignored. However, neither can poor performance.

Positive reinforcement and recognition goes a long way in motivating people and should be liberally and fairly applied.

3.5. Final words

There is a lot at stake in deploying the first wave of SMRs; but, with rigorous planning and proper execution, it can be accomplished very effectively within cost and schedule projections. However, one doesn’t have to look far in the nuclear industry (or any other industry with large capital projects) to find situations where responsible and well-meaning individuals and corporations fail to deliver on a complex project. Two of the many lessons the nuclear industry has learned (or should have learned) from past failures are: a.) experience counts and b.) accurate objective project planning and reporting is essential.

The nuclear industry has achieved technical excellence far exceeding any objective expectations. A significant contribution to that excellence is a well-defined and well-executed quality assurance and quality control program. QA/QC personnel operate as independent objective overseers reporting outside the project management organization.

For a multi-billion dollar project, isn’t a similar “Commercial Quality Control”⁴; function in order for the wide range of activities that affect cost and schedule and other project management functions? Effective objective observers/advisors who are not encumbered by the fog of daily activity, who understand the problems of the past and the best practices of the present, and who are focused exclusively on project success without personal or company agendas can contribute significantly to the likelihood of project success.

There is precedence. Independent and objective experts, serving as non-adversarial Commercial Quality Control overseers have made a difference on a number of large capital projects, including nuclear units. SMR stakeholders should give serious consideration to Commercial Quality Control.

James Cater is former navy nuclear submarine officer, civilian executive, management consultant, and entrepreneur with degrees in engineering, business and law. He has managed nuclear refurbishment projects as well as major new nuclear build construction and commissioning programs. As an executive consultant, Mr. Carter advised managers and executives on a variety of strategic and tactical issues. He has also served on corporate boards including: an SMR developer, a bank, a consulting company, and several startup companies. Today, he devotes time to multiple business interests and consults on energy matters, technology commercialization, and large capital project management.

³ Construction Industry Institute SP17-1 “In Search of Partnering Excellence.”

⁴ American Nuclear Society – Nuclear News June 2007.