MPR-2627
Revision 2
September 24, 2004

DOE NP2010 Construction Schedule Evaluation

Prepared for the U.S. Department of Energy
under contract DE-AT01-020NE23476

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U.S. Department of Energy

Executive Summary

As part of the U.S. Department of Energy (DOE) Nuclear Power 2010 (NP2010) initiative, MPR evaluated the project and construction schedules of four proposed nuclear power plants: the Toshiba Advanced Boiling Water Reactor (ABWR), the General Electric Economic Simplified Boiling Water Reactor (ESBWR), the Atomic Energy of Canada Ltd. (AECL) Advanced CANDU Reactor (ACR-700), and the Westinghouse Advanced PWR 1000 (AP1000). This report is prepared for the DOE under contract DE-AT01-020NE23476.

This evaluation is related to an effort led by Dominion Energy to not only evaluate construction schedules, but also to study construction technologies, staffing requirements and costs, and decommissioning funding requirements for the four proposed plant designs. The Dominion Energy Study and this evaluation both include reviews of advanced reactor construction schedules, but employ different approaches. The Dominion Energy Study is in Volume 1 of the combined document produced for DOE by Dominion and MPR. The two MPR reports, this one and the report, “Application of Advanced Construction Technologies to New Nuclear Power Plants,” are in Volume 2.

The construction schedules proposed by all four vendors are significantly shorter than those previously achieved in the U.S. Therefore, the purpose of this particular evaluation was to assess the feasibility of the schedules by determining:

- If the key assumptions were valid and if all critical assumptions were represented.
- If the schedule scope included all pertinent activities.
- If task durations were realistic relative to historical precedent and current standards.
- If the schedule logic was sequenced in a reasonable manner.
- If modularization was used in the design and whether its consequences were incorporated throughout.
- If the critical path scope was complete and the logic was reasonable.
- If the vendors performed a risk assessment and what were the significant conclusions.

Because data was provided by the vendors in a variety of forms, using different assumptions, and with varying levels of detail, it was not possible to make one-to-one assessments for all aspects of the schedules. Accordingly, the evaluation focused on expected activities, level of detail, project critical paths, and key assumptions.

Overall, our general conclusions fall into seven major categories: 1) the status of the nuclear industry, 2) overall schedule improvements compared with previous U.S. experience, 3) impact of project management and organizational structures, 4) influence of modularization and construction planning, 5) interactions with regulators and new regulatory processes, 6) impacts of key vendor assumptions, and 7) insufficiently defined areas. The scope of this MPR evaluation does not include the effects of plant staffing on construction and operations. We provide recommended actions highlighting specific industry and DOE initiatives for each of these categories.

A discussion of plant-specific conclusions and recommendations follows the general recommendations. The conclusions and recommendations provide important information for all decision-makers involved in the goal of operating a new nuclear plant by 2010. This includes, but is not limited to, the DOE, the corporate nuclear industry, potential plant owners, Nuclear Steam Supply System (NSSS) vendors, and other suppliers of nuclear equipment.

Status of the Nuclear Industry

In general, each vendor has prepared a well-developed construction project schedule[1]. The milestones within all of the schedules appear to be achievable. However, the feasibility of the schedules for near-term construction is dependent upon cooperative efforts between NSSS vendors, utilities, architect engineer (A/E) firms, and DOE to complete the significant additional work that remains. Additionally, support and cooperation will be required from the U.S. Nuclear Regulatory Commission (NRC) and other regulatory bodies.

We note that some vendors are further along in the design, licensing and commercialization processes than others. This is attributable to the varying use of evolutionary designs (i.e., AP1000 based on AP600 and ESBWR based on ABWR), different levels of experience in relating with the NRC in licensing new technologies, and the ability of some NSSS vendors to draw on recent, international nuclear construction experience. Based on the schedules provided and the pre-construction conditions that must be satisfied, it does not appear likely that any vendor could support commercial operation by 2010. Yet, with continued cooperative effort, achieving the goal of new operating nuclear power plants in the 2010 timeframe is feasible.

It is important for the industry to focus its effort on the areas of greatest risk described below. We recommend thoroughly planning all required activities in greater detail to enhance the industry's ability to meet schedule and cost goals for the new plants.

We recommend that DOE and the industry continue to closely examine and place priority on those activities that must occur prior to the start of construction. Scheduling and financial support should be provided to complete those activities. Advances in this area are being made through the DOE COL Licensing Demonstration Project. This project will test the COL process by supporting consortia of utilities, vendors and constructors in obtaining a COL license from the NRC. To further assist the consortia in preparing these applications, DOE and the industry are participating in a cost-shared project to support NEI in developing the "COL Process and Application Guidance" document (NEI 04-01, Reference 1.11). This document should guide applicants in preparing COL applications in a thorough and timely manner.

In addition to these initiatives, the "DOE/Nuclear Power Industry Strategic Plan for Light Water Reactor Research and Development" ("DOE/Industry Strategic Plan," Reference 1.10) addresses many of the near-term steps that must be completed prior to the construction of a new plant.

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[1] GE intends to use much of the ABWR schedule and construction plan for the ESBWR. Even though a schedule does not exist explicitly for the ESBWR, GE's construction project schedule is considered to be well-developed because of potential synergy with the well-developed ABWR information.

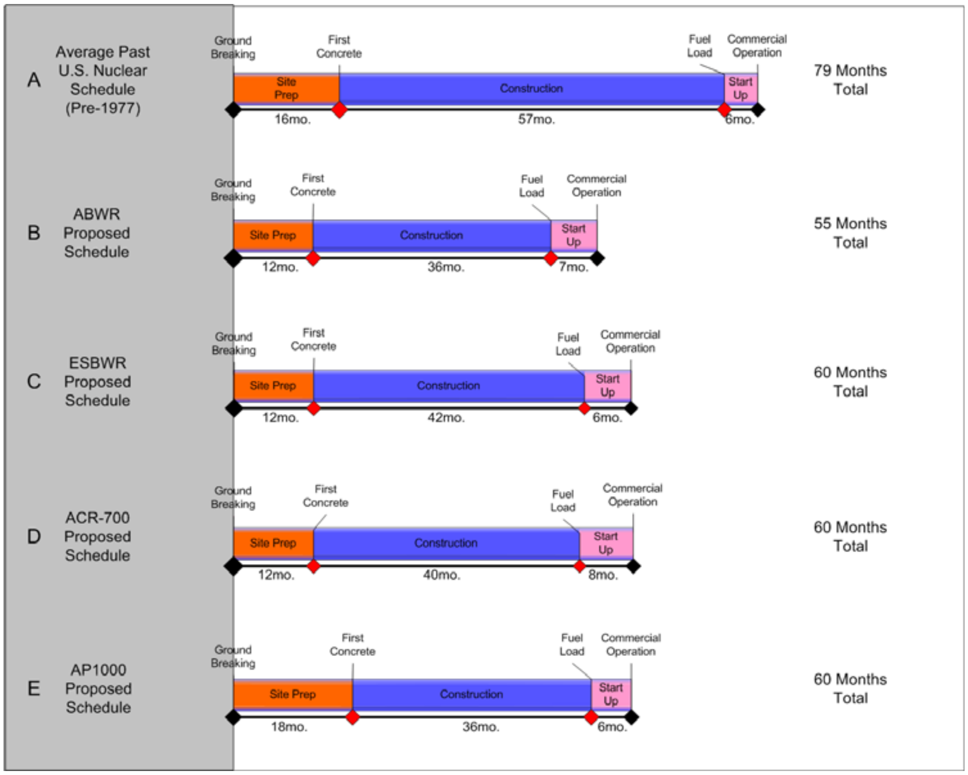

Figure ES-1. Past versus Proposed U.S. Nuclear Construction Milestone Schedules

Overall Schedule Improvement Recommendations

As Figure ES-1 shows, the proposed schedules are significantly shorter than previously achieved in the U.S. Universally, designers of new reactors place great faith in the ability of a stable regulatory environment, extensive planning, completing plant-specific engineering and drawings prior to start of construction, modularized construction techniques, and well-defined project organization to achieve the proposed, aggressive construction schedules. To attain these goals, we recommend that the nuclear industry:

- Establish the likely scenarios for project organization and the timing of licensing activities and plan construction schedules around those scenarios accordingly,
- Account for the First-of-a-Kind (FOAK) planning to support modularization and other new construction technologies,
- Work with U.S. manufacturing companies that fabricate modules in other industries (power generating station construction, naval, etc.) to benefit from their experience and more efficiently produce nuclear-safety-related equipment, and
- Continue and expand efforts to cooperate with the NRC to effectively and efficiently develop and implement the licensing procedures detailed in 10 CFR Part 52, particularly the process of obtaining a Combined Construction and Operating License (COL).

Many of these recommendations are already being cultivated by DOE through the DOE / Industry Strategic Plan (Reference 1.10) and NEI 04-01 (Reference 1.11). It is expected that as the COL application process is further applied and tested in the COL Demonstration Project and actual project organization structures are planned that vendors and potential owners will update their overall project schedules.

Project Management and Organizational Structures

Preliminary applications to build new nuclear power plants in the U.S. require the cooperation and investment of utilities, NSSS vendors, and A/E firms as well as input from other potential financial investors. Several different scenarios are possible for how these parties will align themselves. The resulting consortium should make roles and responsibilities clear from the outset to best facilitate the licensing and construction processes. Each phase of the process will need to be considered and an appropriate chain of command determined.

For example, during the COL application phase, the consortium needs to have decided among the NSSS vendor, sponsoring utility and, potentially, a construction firm who will have control over construction activities, who will interface with the necessary regulators, how input to the remaining engineering activities will be handled, and who will be accountable to plant investors. All of the organizations involved have an interest in these activities, but a muddled hierarchy of decision-makers could lead to significant delays. A clear delineation of responsibility up front will aid in ensuring that activities are both efficiently and capably completed. Some aspects of these teaming agreements made during the COL application phase should later be applicable to the contractual agreements required for plant construction. It is expected that vendors and utilities will evaluate options for project structures for new plant construction as part of arrangements for an actual order.

Modularization and Planning

All the new reactor designs and construction plans call for a high degree of modularization to reduce the duration of critical path activities, move significant portions of the construction work offsite, and decrease the quantity of bulk supplies (i.e., pipe, valves, hangers, etc.) that must be installed on-site. Modularization can yield these benefits and others; however, this construction technique also requires a great deal of up-front engineering and planning to ensure an orchestrated execution. Accordingly, we conclude the following:

- NSSS vendors and the organization taking the lead in the construction of the new plant (whether A/E, construction or the nuclear utility) should maximize the use of 3-dimensional computer modeling to understand the interconnections among modules and throughout the entire plant. These tools can anticipate and prevent installation issues such as hitting unanticipated rebar when installing pipe hangers or misalignment of pipe connections between adjoining rooms and buildings. Effective use of modeling tools can aid in preventing in-the-field construction delays by anticipating issues with module fits and equipment installations.
- NSSS vendors and module fabricators should increase communication regarding the procurement times necessary for the various systems and the capacity of the fabricators to produce multiple modules in a short period of time. As it is believed that there are a limited number of fabricators with the capabilities and credentials to build nuclear modules, this is a significant concern if multiple plants are ordered simultaneously.

- Vendors should revisit the engineering and planning time allotted to support the use of modularization and other new construction techniques to ensure that sufficient durations have been provided. See MPR-2610, "Application of Advanced Construction Methods to New Nuclear Power Plants" for more information on the implementation of modularization and other advanced construction techniques.

- It is not clear that vendors have fully assessed and planned for all the prerequisites for using advanced construction techniques and specialized equipment (e.g., training, transportation and equipment set-up). Vendors should review the availability of specialized equipment and the transportation requirements needed to achieve construction schedules. Additionally, the requirements for training on these tools and techniques should be assessed. Procurement, transportation, and training needs should be incorporated into pre-construction schedules.

It is expected that vendors will work with constructors to establish timelines and plans for fulfilling prerequisites that are essential to shortened construction schedules. DOE is currently supporting the resolution of these concerns through the development of new construction technologies as addressed in Objective 1-3 of the DOE / Industry Strategic Plan (Reference 1.10).

Regulatory Issues

The nuclear industry, NRC, DOE, and financial investors understand that the licensing process established under 10 CFR Part 52 revolutionizes the way new nuclear power plants will be licensed, constructed, and operated. With this change, the regulatory environment should become more efficient and stable. However, the complete process of licensing a new nuclear power plant for operation remains untested. These new reactor designs are the first to prove the new process in its entirety. The vendors' proposed schedules show a range of licensing timelines, which reveals that the expected durations are still uncertain. Furthermore, the licensing process continues to evolve as it is tested, which may introduce delays into the planned schedules. Licensing delays are of particular concern for the first plants to be constructed and appropriate contingencies should be included in these schedules.

The DOE COL Licensing Demonstration Project will address many of these concerns by providing the framework and precedent for an owner-vendor-constructor team to submit a COL application to the NRC. This project will encourage vendors to further define engineering and design activities necessary for licensing and work with the NRC to establish application requirements and timelines.

Key Vendor Assumptions and Impacts

The assumptions vendors made to develop their construction schedules are potential areas of risk. Thus, there are a number of conclusions that relate to schedule assumptions.

- Each vendor assumed that an unlimited cash flow would be available early in the construction project to support the completion of plant-specific engineering and begin the procurement process for long-lead items. Having these funds readily available at construction inception does not accurately represent the likely U.S. market. The vendors should investigate potential cash flow limitations, especially those placed early in new construction projects, and incorporate these limitations into their schedules.

- Each vendor assumed that an unrestricted labor workforce would be available. This does not accurately represent the U.S. labor market, particularly personnel qualified to perform nuclear safety-related work. While difficult to accomplish prior to site selection, potential owners and constructors should survey labor availability near potential plant sites. This information should then be incorporated into the schedules.

  DOE has begun to address this concern through Objective 1-4 of the DOE / Industry Strategic Plan (Reference 1.10). The DOE should continue to assess the construction infrastructure required to restart the building of new nuclear plants in the U.S. and compare this to the available infrastructure. The timetable required for industry actions to account for any shortfalls between the required and the actual should then be established and disseminated to the industry to promote awareness of the lead time required to have the infrastructure available at construction start.

- Site selections affect the versatility of the vendor project schedules. For example, those that assume only rail and road access are considered more conservative than those that only assume water access. The industry should continue to use caution when evaluating site-specific assumptions within schedules.

- Each vendor assumed that engineering activities would be substantially complete at the time of project initiation. Engineering and planning effort remains for all designs (although most activities are complete for the ABWR[2]). Additional studies to identify and fund detailed engineering activities required for COL applications and construction should be supported with appropriate adjustments to schedules. Per our recommendations, these studies could include anticipating and preparing for Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC), reducing the complexity of the qualification process for software and digital controls, and determining the need for and availability of specialized construction equipment to support the best and fastest fabrication practices.

  DOE efforts already underway to address these concerns include activities under Objectives 1-1 and 2-1 of the DOE / Industry Strategic Plan (Reference 1.10), and the COL Demonstration Project. Additionally, the NRC and Westinghouse are performing an ITAAC Pilot Project to exercise the planned NRC / vendor interaction by treating a major equipment project (e.g., a steam generator replacement) as a new construction project with all the necessary ITAAC involved.

- Each vendor assumed that relationships with component supply vendors would be established in a timely fashion. These relationships should ensure that procurements can be managed within the constraints of the critical path. While vendors have been established for recent international nuclear construction projects, U.S. modularization fabrication facilities and workforce are untested and potentially inadequate in number. The use of foreign vendors could impede schedule progress due to differences in Quality Assurance (QA) programs, difficulties in interacting with the NRC, and insufficient testing to meet U.S. requirements. However, with careful planning, foreign vendors are currently being

[2] Note that the Toshiba ABWR is not exactly the same as the GE ABWR that received Design Certification from the NRC in 1997. Relative to the other plants under consideration in this report, the design is far more complete because it has been constructed and is currently operating in Japan. However, there are some configuration differences that must be reconciled between the GE and Toshiba designs before the Toshiba ABWR may be constructed and operated in the U.S.

used in the U.S. to supply and install steam generators, reactor pressure vessel heads and other equipment without significant problems. To deepen the connection between NSSS vendors and component supply vendors and ensure that all necessary controls are in place when construction begins, the NSSS vendors should establish the necessary relationships and work with the component supply vendors while completing detailed engineering. Vendors should also carefully consider the role of the NRC in fabrication and inspection activities and coordinate interactions accordingly.

Objective 1-4 of the DOE / Industry Strategic Plan (Reference 1.10) includes an assessment of the fabrication / manufacturing infrastructure that will be required for specialized equipment and should identify sources for the supply of major nuclear plant systems and components.

Insufficiently Defined Areas

During this evaluation, we identified several additional issues, such as FOAKE activities and operator training, that were weakly defined or addressed. These activities could affect the critical path. The DOE, vendors, the nuclear industry and potential owners should pay particular attention to these issues as construction plans are finalized.

- Significant FOAKE activities remain for three of the reactor designs. Ongoing engineering can result in design changes. In turn, the schedules could be impacted by new design requirements. It is critical to identify changes early in order to reduce their impact on the schedule. As noted previously, ongoing FOAKE definition projects are beneficial because they will help to move this work forward. As those efforts continue, the potential impacts of FOAKE on the project schedules should be re-assessed.
- Operator training and procedure preparation activities are generally omitted or loosely defined within the vendor schedules. This includes the development, construction and use of a plant simulator. These activities could impact critical path. Therefore, vendors and utilities should detail the training and procedure development processes that will be required for the new plants so that they may be incorporated into the project schedules.
- Digital controls designs for the main control room and plant simulators are also omitted or loosely defined within the schedules. Because the simulator is required for operator training, and operators are needed for plant testing, these activities could impact critical path. Additionally, the U.S. regulatory requirements that will be placed on new digital controls are largely untested. This raises the risk of schedule increases. The DOE is mitigating some of these risks through the COL Demonstration Program, which will better define the digital I&C design. It is expected that NSSS vendors will perform sufficient design of the digital I&C design for their COL applications to result in licensing by the NRC, and that the approach to completing the I&C system detail design will support early resolution of issues to avoid plant construction or commissioning delays.
- NSSS vendors cannot provide a thorough list of Inspections, Tests, Analyses and Acceptance Criteria (ITAAC) until the NRC completes the process of defining requirements for ITAAC (especially programmatic ITAAC). Additionally, the NRC may identify specific ITAAC during the Design Certification (DC) process. However, most submitted schedules omitted or only roughly outlined ITAAC activities in their schedules. To exhibit readiness and minimize the potential for ITAAC to negatively affect the

licensing and construction schedules, vendors should submit a list of ITAAC, commensurate to current NRC requirements, with the COL application. Vendors should use the results of the NRC Construction Inspection Program pilot projects to support their COL applications and estimate effort and durations for future schedules based on the results of ITAAC demonstration projects being performed by NRC, DOE, NEI and NSSS vendors.

- Detailed design activities that are not completed / resolved during the DC process will add to the engineering time required for the COL application process and, possibly, the construction schedule. The vendors should recognize these open areas as early as possible and, at least for the first unit of a design, incorporate additional schedule time as necessary. The DOE COL Licensing Demonstration project will advance the engineering completion of the plant designs by emphasizing the goal of obtaining a COL.
- The schedules provided did not have installation rates for the various commodities and labor productivity rates clearly stated. It is expected that vendors and constructors will prepare resource-loaded schedules with clear references for commodity installation rates as plans are further developed. As rates become available, potential owners should perform due diligence assessments to determine whether schedules are realizable.

General Recommendations

To address the conclusions of this study, the following table provides general recommendations. Where we could identify actions in progress or planned by DOE and other organizations, these actions are summarized. Additional actions are recommended as necessary.

Summary of General Recommendations and Action in Progress

General Recommendation Number	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR1	Work needed to prepare for construction (such as preparation of COL applications and obtaining NRC approval, establishment of project team organization, establishment of financing, etc.) must have few or no outstanding issues remaining at construction start to enable construction teams to accomplish the short construction schedules planned.	DOE and industry should closely examine those activities that must occur prior to the start of construction and provide the resources and financial support required to complete them.	DOE has issued a solicitation for a COL Demonstration Project to test the COL process by obtaining a COL license from the NRC. It is expected that the nuclear industry team in this project will also develop detailed plans to accomplish preparations for construction of a plant. The DOE/Nuclear Power Industry Strategic Plan for Light Water Reactor Research and Development, February 2004, ("DOE / Industry Strategic Plan") also addresses many of the steps necessary for construction of a new plant.	None.

General Recommendation Number	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR2	See finding for GR1 above.	DOE and industry should continue efforts to submit COL applications. As progress is made, schedule estimates should be updated to reflect new information. Scenarios of licensing schedules for both FOAK and NOAK plants should be reviewed to address acceptable risk prior to COL issuance.	Under a DOE / Industry cost-shared project, NEI is developing a COL Application Guidance document (NEI 04-01 document) to assist power companies in preparing COL applications. This document is planned to be provided to the NRC for review and comment in December 2004. The DOE COL Demonstration Project will result in an owner-vendor-constructor team submitting a COL application.	It is expected that vendors and potential owners will update overall project schedules based on actual time to prepare and obtain COL, extent of ITAAC developed, and actual business arrangements planned. Also, potential owners should review actual time to obtain COL and work with NRC to streamline the COL process for NOAK plants.

General Recommendation Number	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR3	Although the NRC identifies some Inspections, Tests, Analyses and Acceptance Criteria (ITAAC) during the Design Certification (DC) process, the complete list of ITAAC will not be available until a COL application is prepared and approved by the NRC. The schedules reviewed omitted or only roughly outlined ITAAC activities.	No *general* increase in construction schedule float is recommended to address uncertainty with regard to ITAAC within the construction phase of the project schedules. As the regulator further defines ITAAC, vendors should define the detailed activities within their schedules that will be required to support ITAAC resolution. As plans progress for FOAK plants, vendors should update their schedules to incorporate the most realistic and accurate estimates of the schedule impact of regulator inspections and other activities.	DOE / Industry Strategic Plan Statement of Work (SOW) for Objective 1-1 includes a demonstration project to assure "ITAAC verification can support an aggressive construction schedule." NRC and Westinghouse are performing an ITAAC Pilot Project to exercise the vendor/NRC interaction by treating a major equipment project (such as SG replacements) as a new construction project and exercising the ITAAC process.	Vendors and constructors should insert ITAAC inspections and preparation into schedules and incorporate results of development of the ITAAC and NRC Construction Inspection Program processes in project schedules with effort and durations based on the outcome of ITAAC demonstration projects by NRC and DOE and ITAAC definition efforts by NEI and NRC.
GR4	Schedules vary in the level of detail and preparation regarding steps needed to obtain COL license and a plant construction contract. Some assumptions regarding the level of effort and timetable for these steps are not well-supported.	Industry should develop an all-inclusive list of remaining activities required for FOAK plants. This will help to focus near-term support for remaining technical and programmatic activities.	The COL Demonstration Project will also define remaining engineering and detail design activities. It is expected that vendors will continue to assess design certification and COL licensing efforts as well as the activities for detailed plant design necessary for FOAK plant licensing and construction.	None.

General Recommendation Number	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR5	Plant project team structure (minimal or zero changes by owner after order, rigid assignment of authority for decision-making, high pre-construction level of effort, etc.) must be different from previous projects to support achievement of the shorter construction schedules.	Vendors, utilities, and potential investors should evaluate the options for organizational and project management structures that will be best suited to the construction of a new nuclear power plant. These structures should include contractual arrangements and a detailed chain-of-command for various decision making processes.	Vendors and utilities are teaming to respond to the DOE COL Demonstration Project solicitation. Some aspects of these teaming agreements should be applicable to a contractual arrangement leading to plant construction. It is expected that vendors and utilities are evaluating options for project structures for new plant construction as part of contract arrangements for an actual order.	None.

General Recommendation Number	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR6	Each vendor assumed that cash flow would be available as needed to support completion of engineering and the procurement of long-lead items. The need for a high level of design completion and funding of pre-fabrication of modules and long-lead time items to facilitate modular construction and reduced on-site construction time will alter the pattern of cash flow needed to fund future projects relative to previous nuclear plant construction projects.	A group of utilities considering constructing a new plant should investigate potential limits that will be placed on cash available to fund activities early in new nuclear construction projects. Also, this group should address what investment risks the industry believes it would be willing to take with respect to beginning long-lead item procurement and site preparation prior to the issue of COL.	None.	As potential owners, constructors, and vendors proceed towards establishing a project structure and contractual arrangement for plant construction, they will have to incorporate the effect of cash flow limitations into the project schedule.

General Recommendation Number	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR7	Present schedules do not address man-loading or labor availability. Labor availability will lengthen the construction schedule if shortages of critical skilled crafts reduce the number of shifts or man-hours that can be applied to construction activities.	While it is difficult to predict labor availabilities without first identifying the plant location and timeline for construction, the industry should evaluate the labor availability near possible plant sites. Additionally, vendors and constructors should use this data to modify the schedules to balance resource availability and schedule length.	DOE / Industry Strategic Plan Statement of Work (SOW) for Objective 1-4 includes an assessment of "adequacy of nuclear training pipeline and skilled construction trade sector to support near-term deployment." Vendors and constructors are planning to assess the construction trade sector in the regions of early site permit applications or where there is utility interest in construction.	DOE should assess the construction infrastructure required to restart building of new nuclear plants in the U.S. and compare this to the available infrastructure, then analyze the timetable for industry actions needed to make up shortfalls. This assessment should be disseminated to make industry aware of the lead time to have needed infrastructure available at construction start.
GR8	Significant FOAKE activities remain for three of the reactor designs. Ongoing engineering can result in design changes that could impact schedules. It is critical to identify changes early in order to reduce their impact on the schedule.	An ongoing NP2010 effort to identify remaining FOAKE work is an important step toward achieving the necessary level of engineering completion. Detailed engineering activities needed to support COL applications and construction should be completed by the vendors in the near term. DOE should consider cost sharing assistance for vendors to complete these activities.	DOE NP2010 Program COL Demonstration Project will advance the engineering completion of the reactor designs involved as needed to support obtaining a COL. Also, DOE / Industry Strategic Plan SOW for Objective 1-2 includes design completion of "near-term Generation III+ designs that industry is willing to consider for a plant order."	It is expected that vendors and architect/engineers will identify changes to construction schedules required by the detailed design and licensing process and will ensure these are analyzed promptly to reduce risk of schedule increase.

General Recommendation Number	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR9	Operator training and procedure preparation activities are generally omitted or loosely defined within the vendor schedules. This includes the development, construction and use of a plant simulator. These activities could impact critical path.	Vendors and utilities should prepare plans for training activities that will be required prior to operation of the new NPPs. The plans should then be integrated into the existing schedules to reveal impacts to both FOAK and NOAK construction schedules.	None.	It is expected that vendors will determine the required effort to develop training plans needed to support testing, commissioning, and operation of a Gen III+ plant. The resources required to carry out training and integrate the training timeline into the construction schedules will then be included.
GR10	Digital control systems and control room simulators are untried in the U.S. regulatory environment, and Gen III+ design certifications defer definition of the I&C system to the COL application phase. The schedule risk posed by delays in design and licensing of digital control systems is significant.	Additional development is necessary by all vendors to define the design, licensing, procurement, construction, and testing activities related to digital controls and simulators for the new NPPs. This should include discussions with the NRC about the requirements that will be used to review the digital control and the simulator designs to ensure that regulator expectations will be met.	DOE / Industry Strategic Plan SOW for Objective 2-1 includes completion of FOAKE for Generation III+ plants, to include design of digital equipment. The COL Demonstration Project, which supports DOE / Industry Strategic Plan SOW for Objective 1-1, should result in definition of the digital I&C design and the licensing approaches for the plant(s) involved, as well as a COL that licenses that design.	It is expected that NSSS vendors will perform sufficient design of the digital I&C systems for COL applications to result in licensing by the NRC, and that the approach to completing the I&C system detail design will support early resolution of issues to avoid plant construction or commissioning delays.

General Recommendation Number	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR11	Each vendor assumed that relationships with component supply vendors would be established in a timely fashion. To enable the proposed schedules, these relationships must ensure that components can be delivered within the constraints of the critical path.	Component vendor relationships should begin to be established by vendor and constructor teams as soon as possible. Early detailed engineering efforts should be coordinated with the fabricators to ensure that the designs are constructible and can be delivered to support the construction schedule.	DOE / Industry Strategic Plan SOW for Objective 1-4 includes an assessment of fabrication/manufacturing infrastructure for specialized equipment and is meant to identify sources for all major nuclear plant systems and components. NSSS vendors are working to locate sub-suppliers for required equipment.	It is expected that NSSS vendors will give sufficient priority to the establishment of plant equipment procurement plans to support the construction schedule.
GR12	A significant portion of plant equipment is expected to be fabricated outside the U.S. Although large special equipment such as steam generators and RPV heads are imported now, the increased volume and scale of importation for new plants could be a QA and logistical challenge to the schedules.	The NSSS vendors and constructors should review the policies and requirements that are imposed on foreign-manufactured or safety-related equipment and determine the extent of the schedule impact of developing quality programs, especially by smaller component vendors. Also, the effect of potential customs and shipping delays on the schedules should be reviewed.	DOE / Industry Strategic Plan SOW for Objective 1-4 includes an assessment of fabrication/manufacturing infrastructure for specialized equipment and is meant to identify sources for all major nuclear plant systems and components. NSSS vendors are in the process of identifying sub-suppliers for major components.	It is expected that NSSS vendors will work with sub-suppliers to establish QA processes that ensure equipment meets requirements, to verify supply chains will support the aggressive construction schedules, and to plan the coordination of their fabrication and inspection activities with the NRC.

General Recommendation Number	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR13	The construction methods proposed for use are assumed to be available and are heavily dependent on new construction technologies requiring specialized equipment. It is not clear that these assumptions are valid or that vendors have identified or planned how to meet the prerequisites (e.g., training, transportation, equipment set-up) to enable use of these technologies.	The vendors should review the availability and transportation requirements for the specialized equipment required to achieve construction schedules. Additionally, the requirements for training on these tools and techniques should be assessed. Preparations for use of new technologies key to shortened construction schedules should be planned into project schedules as part of pre-construction work.	DOE / Industry Strategic Plan SOW for Objective 1-3 includes development of construction technologies to shorten construction schedules for new nuclear plants. MPR is also preparing report MPR-2610 "Application of Advanced Construction Methods to New Nuclear Power Plants" for DOE that identifies and provides recommendations for enabling the use of advanced construction technologies.	It is expected that vendors will work with constructors to establish timelines and plans for fulfilling the prerequisites to enable the construction techniques that are key to the shortened construction schedules.
GR14	The schedules provided did not have installation rates for the various commodities clearly stated. Thus, the feasibility of achieving these rates could not be evaluated.	Installation rates assumed in the schedules should be evaluated by the vendors and constructors to ensure that they are feasible.	None.	It is expected that vendors and constructors will prepare resource-loaded schedules with clear references for commodity installation rates to enable potential owners to perform more thorough due diligence in assessing whether construction schedules are achievable.
GR15	Vendors do not yet have resource-loaded schedules and thus their assumptions about labor productivity and shifts/working hours could not be evaluated.	The vendor schedules should be resource-loaded to allow for further examination of schedule feasibility.	None.	See Additional Action for GR14 above.

Plant-Specific Conclusions

In general, each of the vendor schedules for site preparation, construction, and start-up and final commissioning appear achievable. However, several plant-specific items could increase the project durations if mitigating actions are not taken.

The table on the following page highlights the vendor-estimated duration of each schedule, the status of the project, and major plant-specific aspects of each schedule that need to be further developed to minimize risks to each plant's constructability.

Summary of Plant Construction Schedules

Plant	Vendor-Estimated Duration (months)		First of a Kind (FOAK) or Nth of a Kind (NOAK) Schedule	Project Status	Primary Uncertainties in Schedule
	First Concrete to Fuel Load	Ground-breaking to Commercial Operation			
ABWR	36	55	NOAK	The GE ABWR, which has some differences with the Toshiba ABWR, received DC in 1997. Specific licensing plans for using the Toshiba ABWR in the U.S. are pending.	U.S. labor and regulatory requirements will differ from those in Japan. Relationships with domestic vendors must be established. Transportation durations rely on use of a barge, which may not be available for many U.S. sites. Control Room / Simulator schedule, licensing inspections, and ITAAC activities require additional detail.
ESBWR	42	60	FOAK	Pre-Application phase with NRC; DC application expected to be submitted mid-year 2005.	Detailed engineering of systems and buildings have not yet been developed for the ESBWR, plan relies heavily on synergy with ABWR. Shop testing and system turnover activities are not sufficiently planned for in the schedule. Licensing inspections and ITAAC events require definition and development.
ACR-700 (1st of twin units)	40	60	FOAK	Pre-Application phase with NRC; DC application expected to be submitted Fall 2004 (Reference 4.5).	Resource limitations (labor availability, specialized equipment, etc.) have not been applied or addressed within the schedule. Additional justification should be provided for reduced site preparation and shop testing durations. Control Room / Simulator development and training activities require further detail. Licensing inspections and ITAAC require definition and development.
AP1000	36	60	NOAK	DC application submitted March, 2002; DC expected December 2005.	Many of the assumptions made for the NOAK schedule would need to be adjusted for the FOAK schedule. Further development of the potential differences in the FOAK schedule is recommended. Fabricator testing and qualification activities require further detail. Control Room / Simulator development and training activities require definition and development. Licensing inspections, reviews, and ITAAC require further detail.

Plant-Specific Recommendations

Specific recommendations for activities to address some of the uncertainties described in the preceding table are summarized below. Note that many of these topics are also addressed in the general recommendations and reactor vendors may have already begun to resolve them. While all recommendations require action by the vendors, other parties such as the DOE, regulators or potential owners may also be able to contribute to their resolution. Where applicable, these contributing actions are noted in parentheses. The numbers (e.g., GR1) within the notes refer to applicable general recommendations summarized in the table beginning on page *xi* (duplicated as Table 3-1). More information regarding the plant-specific recommendations can be found in Section 4 of the report and in the plant-specific appendices.

ABWR

- Toshiba must resolve issues with the use of the GE ABWR DC and reconcile technical differences between the GE and Toshiba designs which may hinder the COL process. *(Vendor, potential owners and regulator must collaborate to resolve technical and licensing concerns)*
- Further develop the implications of site preparation, testing and commissioning in the U.S. versus abroad. *(General recommendations GR2 and GR12 apply.)*
- Revise the construction schedule assuming a specific U.S. site (perhaps based on ALWR requirements) and fully incorporating site-specific engineering activities. *(Potential owners and constructors could assist in defining the U.S. site and conducting more extensive studies.)*
- Conduct a study to determine the remaining quantity of additional design work that will need to be performed to increase the amount of modularization in the ABWR. *(The vendor, A/E firms and constructors should collaborate for this study)*
- Review procurement durations to ensure that adequate time is provided to develop new relationships, as necessary. *(General recommendations GR11 and GR12 apply; potential owners, constructors and the vendor should determine what relationships already exist and investigate the ability of those relationships to meet project needs.)*
- Further evaluate transportation methods and durations for large components and modules to ensure that they are achievable within the U.S. *(General recommendations GR11, GR12, and GR13 apply; potential owners should assess the feasibility of currently projected procurement durations.)*
- Consider the effects of assuming U.S. labor conditions (rather than Asia) in the schedule. *(The vendor, constructors and potential owners should collaborate for the study of these differences.)*
- Examine U.S. labor conditions to determine if the staffing required to support a reduced time period from fuel load to commercial operation is available. *(General recommendation GR7 applies.)*
- Conduct a study of U.S. training regulations and practices to determine if the assumed personnel training is consistent with U.S. requirements. Incorporate all necessary training requirements, including developmental activities, into the schedule. *(General recommendation GR9 applies.)*

ESBWR

- Further determine the scope of activities necessary to convert the ABWR plans for ESBWR construction. *(General recommendations GR1, GR4, and GR8 apply.)*
- Investigate relationships with component vendors and add additional schedule time, as required, to support these relationships. *(General recommendations GR11 and GR12 apply.)*
- Develop the schedule basis and plans to facilitate on-site work flow activities. *(General recommendations GR14 and GR15 apply.)*
- Review requirements and plans for shop testing and system turnover activities; provide additional detail and schedule time for these activities. *(General recommendations GR-11 and GR12 apply.)*
- Conduct studies regarding the constructability of the ESBWR once all designs and activities have been fully converted from the ABWR plans.
- Note that, as a result of recent construction experience at Lungmen with the ABWR, GE was able to provide information regarding the schedule required for development of a simulator. While further development will be required prior to constructing and operating an ESBWR simulator in the U.S., GE has demonstrated adequate progress for this stage of the design process. No recommendations for additional action are proposed at this time.

ACR-700

- Re-examine the potential schedule risks associated with aggressively pursuing an Early Site Permit (ESP), DC, and COL in parallel or close succession. *(General recommendation GR2 applies.)*
- Conduct additional studies into the feasibility of achieving the desired manufacturing and procurement schedules. *(General recommendations GR8, GR11, GR12, and GR13 apply.)*
- Obtain additional input from equipment vendors and further develop module designs to ensure that module fabrication durations may be achieved. *(General recommendation GR13 applies.)*
- Evaluate the feasibility and duration required for shipping large equipment if barge access is not available. *(General recommendation GR13 applies.)*
- Review plans for shop testing activities to ensure that sufficient time is allotted to meet U.S. requirements. *(General recommendation GR3 applies.)*
- Further investigate and document the requirements and durations associated with site preparation. *(Potential owners and constructors should assist in defining the U.S. site and conducting more extensive studies.)*
- Further define and develop the scope of work required for the simulator design, construction and operation. *(General recommendations GR9 and GR10 apply.)*

AP1000

- Fully identify shop testing activities and ensure that fabrication durations are sufficient to allow completion of this testing. *(General recommendation GR3 applies.)*
- Review the procurement schedule to determine potential impacts to the critical path if procurements are limited by milestones such as COL issuance. *(General recommendations GR2 and GR11 apply.)*
- Consider the additional time required for the initial approval of "pre-approved" COL application portions. *(General recommendations GR2 and GR3 apply.)*
- Update the risk analysis to consider additional risks of the FOAK schedule vs. the NOAK schedule, utility preferences for early procurements, and potential licensing risks. *(General recommendation GR2 applies.)*
- Identify all engineering activities required to support FOAK construction. *(General recommendations GR1 and GR4 apply.)*
- Continue to develop activities for licensing, inspection and ITAAC activities. *(General recommendation GR3 applies.)*
- Add resource-loading to the schedule based on detailed estimates of labor and equipment requirements. *(General recommendations GR7 and GR15 apply.)*
- Further define and develop the scope of work required for the simulator design, construction and operation. *(General recommendations GR9 and GR10 apply.)*

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1
Introduction

1.1 PURPOSE

This document reports the results of one of the studies carried out as part of the U.S. Department of Energy's (DOE) Nuclear Power 2010 (NP2010) Program in Fiscal Year 2004. Specifically, designers of advanced reactors have proposed construction schedules that are much shorter than those ever achieved for a U.S. nuclear plant. This study independently evaluates the construction assumptions, sequences, and durations proposed by the vendors of the advanced reactor designs. The work reported here is intended to assess the feasibility of the construction schedules for the most promising options being considered by U.S. utilities for deployment in the next decade. The evaluation includes assessments of the schedules for engineering, licensing, long-lead procurements, site preparation work prior to construction, plant construction, and pre-operational and start-up testing. This report is prepared for the DOE under contract DE-AT01-020NE23476.

1.2 BACKGROUND

In February 2001, the DOE organized a Near-Term Deployment Group (NTDG) to examine prospects for deployment of new nuclear plants in the U.S. in this decade. The NTDG would identify obstacles to deployment as well as actions for resolution. In October 2001, the NTDG published "A Roadmap to Deploy New Nuclear Power Plants in the U. S. by 2010" (Reference 1.6). The recommendations of the Roadmap have been used by DOE to form the basis for a new initiative, NP2010. The NP2010 initiative is a joint government/industry cost-shared program to develop advanced reactor technology and demonstrate new regulatory processes leading to a decision for a private sector order for a new nuclear power plant in the U.S. by 2005. NP2010 is an integrated program that aggressively pursues regulatory approvals and design completion in a phased approach to promote the construction and startup of a new nuclear plant in the U.S. in the 2010 timeframe.

Achieving short and accurately predicted construction durations is critical to the financial success of any new power plant project. This is one of the challenges facing the U.S. nuclear industry. Thirty years ago nuclear construction projects in the U.S. took an average of 73 months from ground breaking to fuel load. Current proposed schedules from the evaluated vendors average 52 months. Because the difference between the previous and the proposed schedules is large, it is important to determine to what extent the proposed schedules may be relied upon, and to what extent there are risks that may be mitigated by further government and industry effort.

In order to achieve the goals of the NP2010 program, DOE has initiated studies to evaluate construction time and costs for new nuclear power plants in the U.S. The DOE has selected a team of contractors from nuclear plant construction, architectural engineering, design, and operations experts to carry out these studies.

To aid DOE in achieving NP2010 goals, MPR evaluated advanced reactor construction schedules concurrently with another NP2010 industry cost-shared project. This other project, led by Dominion Energy (Dominion) in association with Bechtel Corporation (Bechtel), also reviewed the advanced reactor construction schedules as a portion of their project scope. MPR participated with the Dominion group; however, the MPR evaluations were conducted in an independent manner. The corresponding Dominion work is referred to as the "Dominion Study" throughout this report.

The Dominion Study is a compilation of three studies of Generation III+ reactor designs. The first study, as mentioned above, was of Advanced Reactor Construction Technologies and Schedules. This study was performed by Bechtel to evaluate innovative construction schedules and methodologies. The second study, Operation and Maintenance (O&M) Staffing and Costs, was conducted by Dominion Energy, with advice and assistance from Entergy Corporation and the Tennessee Valley Authority. The third study, Decommissioning Costs and Funding Requirements, was conducted by TLG Services.

The Advanced Reactor Construction Schedule studies were performed independently by Bechtel and MPR using the same information from the reactor vendors. The goal of these parallel reports was to provide two viewpoints on the status of nuclear construction schedules and technologies. The Bechtel report reviewed the overall construction schedules for project readiness using construction industry methods. Bechtel also focused on incorporating knowledge and judgment from their extensive power plant construction experience. MPR focused on evaluating details of the vendor schedules for completeness and reasonableness to identify project risks and recommend actions to mitigate those risks. In addition, MPR evaluated advanced construction technologies to identify any technologies that could significantly shorten construction schedules, but require further research and development to implement. The evaluated technologies were selected in collaboration with the Bechtel team. The results of the technology evaluation are documented in MPR-2610, "Application of Advanced Construction Methods to New Nuclear Power Plants."

The Dominion Study and the MPR reports are assembled for delivery to DOE as two volumes comprising the overall work in this area. The three studies that make up the Dominion Study are in Volume 1 of the overall document. This MPR report and MPR-2610 are included in Volume 2.

Information on the background of plant schedule development is located in Section 1 of the Plant Appendices (A, B, C, and D).

1.3 Scope

MPR was asked by DOE to evaluate the schedules for the advanced reactors listed below. These are the reactors considered eligible for near-term U.S. deployment.

- Toshiba (Toshiba): Advanced Boiling Water Reactor (ABWR)[3]
- General Electric (GE): Economic Simplified Boiling Water Reactor (ESBWR)
- Atomic Energy of Canada Limited (AECL): Advanced CANDU Reactor (ACR-700)
- Westinghouse Electric Company (Westinghouse): Advanced Pressurized Water Reactor (PWR) (AP1000)

The scope of the schedule evaluation included activities from preliminary and conceptual engineering through Combined Construction and Operating License (COL) issuance, site preparation, first concrete placement, fuel load, and commercial operation.

A glossary of terms and acronyms used throughout this report is provided in Appendix E.

1.4 Plant-Specific Evaluation Approach

The four NSSS vendors provided schedule information directly to MPR in response to formal requests made in conjunction with the Dominion Study. Additionally, MPR initiated a limited amount of direct contact with the vendors.

We reviewed this information as well as other available information on design details. We also reviewed applicable in-house and publicly available information.

Our review focused on ensuring that the schedule information is:

- Complete and contains all the necessary engineering, licensing, procurement, construction, start-up, and testing activities.
- Reasonable and possible according to good engineering judgment and in comparison to available benchmarking data.

It is important to note the schedule data from the various vendors is not consistent in format, underlying assumptions, or level of detail. Accordingly, our approach was to evaluate the schedules in a consistent manner to allow for meaningful comparisons among the data provided by the vendors. The following sections detail the evaluations that we conducted for each portion of the study.

1.4.1 Assumption Identification

Initially, we identified the assumptions used to develop each of the four schedules. Key assumptions were identified for the following topics:

- Fundamental Project Assumptions
- Site-Specific Assumptions
- Engineering/Procurement Assumptions

[3] Note that the GE ABWR has been excluded from the scope of this evaluation, however, it is also eligible for near-term U.S. deployment. The GE version of the ABWR is currently under construction in Lungmen, Taiwan.

- Construction Assumptions
- Licensing and Permitting Assumptions

Individual assumptions were evaluated on the extent to which they are realistic to the U.S. construction project environment and the degree of conservatism which they add to the schedules. Schedule assumptions are discussed in Section 2.2 for all vendors.

Note that the subsequent evaluations, discussed below, were conducted with respect to the assumptions presented by the vendors.

1.4.2 Detailed Schedule Evaluation

Each vendor schedule was reviewed for completeness of project schedule scope, the reasonableness of the activity durations, and the appropriateness of the logic ties between schedule activities. We accomplished this by first identifying key activities that were expected to be included in the schedules in some form. These activities are listed later in this section. Then, for each schedule, we summarized those activities that could be characterized within our expected key activities. Scope, duration, and logic ties were then evaluated at this level of detail. Results of the scope, duration, and logic evaluations are located within each plant-specific appendix.

Scope Evaluation

We evaluated each schedule on the basis of whether it contained sufficient level of detail for the expected activities. This evaluation determines whether the schedule is complete. If the level of detail for a given activity or sub-activity was not sufficient to evaluate the duration and logic of the activity, this was noted and no further evaluation was conducted for that activity. However, the potential impact of any missing or weakly defined activity is considered.

Duration Evaluation

Following the scope evaluation, the reasonableness of the activity durations was evaluated. This evaluation determines whether the durations chosen in the schedules are reasonable and consistent with the schedule assumptions. When available, we used man-hour estimates, quantity information, and benchmarking data to make a determination about whether the schedule durations were reasonable. However, in most cases this information was not available. Therefore, we compared historical information from previous nuclear construction in the U.S. [4], as well as from more recent construction abroad, to the proposed durations. Using this information along with engineering judgment, we were able to evaluate the durations. Additionally, we used limited cross comparisons between the schedules to aid in the duration evaluations.

[4] Specifically, U.S. construction schedules were analyzed for Peach Bottom 3, TMI 1, TMI 2, Calvert Cliffs 1, and San Onofre 3 from Reference 1.5.

Logic Evaluation

Following the duration evaluation, we reviewed and evaluated the logic within each schedule. This review determined whether the logic between activity predecessors and successors was reasonable. This activity also included a review of open ends and constraints, where available.

Evaluated Schedule Key Activities

A Engineering
- Conceptual and Preliminary Design
  - Discipline-Specific Activities
  - Simulator
- Detailed Design
  - Discipline-Specific Activities
  - Simulator
  - Modules

B Procurement
- Component Procurement
  - Long Lead Items
  - Bulk Materials
  - Shop Testing and Qualification
  - Transportation
- Module Fabrication and Assembly
  - Shop Fabrication and Assembly
  - Shop Testing and Qualification
  - Transportation
  - On-site Fabrication and Assembly

C Construction
- Site Preparation
  - Soil Preparation
  - Laydown Area Preparation
  - Storage Area Construction
  - Equipment Assembly Area
  - Road Construction
  - Security Construction
  - Temporary Office Space and Services
- Building Construction
  - Reactor Building (Containment Vessel, Shield Building)
  - Auxiliary Building
  - Turbine Building
  - Radwaste Building
  - Diesel Generator Building
  - Annex Building
  - Main Control Building
  - Administration Building
  - Circulating Water Building
  - Transformers and Switchyard
- System Completion and Turnover
  - Transformers and Switchyard
  - Reactor Systems
  - Safety Systems
  - Turbine Generator Systems
  - Main Control Room Systems
  - Simulator
  - Radwaste Systems
  - Electrical Systems
  - Water Treatment Systems
  - Other Plant Systems

D Start-up and Commissioning
- System Testing and Qualification
  - Transformers and Switchyard
  - Reactor Systems
  - Safety Systems
- System Testing and Qualification (cont.)
  - Turbine Generator Systems
  - Main Control Room Systems
  - Simulator
  - Radwaste Systems
  - Electrical Systems
  - Water Treatment Systems
  - Other Plant Systems
- Fuel Loading
- Final Commissioning

E Training
- Operator Training
- Operator Training on Simulator

F Licensing Inspections and ITAAC
- Pre-Fuel Load
  - Engineering Reviews
  - Module Shop Inspections
  - On-site Construction Inspections
  - Testing and Qualification Reviews
- Post-Fuel Load
  - Engineering Reviews
  - On-site Construction Inspections

1.4.3 Impact of Modularization

Each vendor indicated that their schedules rely heavily upon modularization to achieve the shortened construction duration. In order to evaluate the possible schedule impacts, we summarized the extent to which each vendor has used modularization. This review can be found in Section 4 of the plant appendices. Additionally, the impacts of modularization are discussed generally in Section 2.1.3.

1.4.4 Critical Path Evaluation

The critical path evaluation reviews the vendors' critical path construction and commissioning schedules and any available near-critical path schedules. A summary and evaluation are provided for each vendor's critical path schedule. While the emphasis of the evaluation is on the construction and commissioning schedule, engineering, procurement, and start-up issues are also addressed.

Typically, engineering, procurement, and start-up issues are considered to be near-critical path as these activities have the potential to severely delay physical building activities if not properly planned and executed. When possible, critical path and near-critical path schedules are assessed for completeness and reasonableness. Where potential vulnerabilities to the critical path are identified, recommendations are made.

1.4.5 First-of-a-Kind versus Nth-of-a-Kind

Each schedule described either a First-of-a-kind (FOAK) or an Nth-of-a-kind (NOAK) plant construction. FOAK schedules include additional engineering and design activities relative to NOAK schedules. This distinction can lead to many differences between the overall project schedules that are important to note. For example, NOAK schedules tend to optimistically assume engineering and project preparedness, while FOAK schedules do not illustrate the improvements that can be achieved in subsequent projects. We identified the type of schedule provided by each vendor, the implications of that assumption, and their estimates for the delta between FOAK and NOAK schedules. We also identified any areas of concern in the schedule estimates and described the potential risks related to schedule reductions.

The FOAK versus NOAK evaluation is located in Section 6 of each plant appendix. A general discussion about FOAK versus NOAK plants is located in Section 2.2.1.

1.4.6 Summary of Vendor Risk Assessment by Vendor

Several NSSS vendors provided reports on risk analyses they have performed. By examining specific assumptions, probability distributions of contributing factors such as weather and labor problems, and tasks on or near the critical path, the probability of achieving or improving on the predicted durations was determined. These probabilities give a quantitative basis for judging each schedule and the vendor's readiness for implementation.

Additionally, the risk analyses provide a systematic means of categorizing the risks within each schedule. Based on risk rates and sensitivity analyses, vendors can determine which assumptions and risk factors could have the greatest impact on schedule duration. By focusing on these factors early in the project, the vendor can develop targeted risk reduction strategies to minimize setbacks.

In Section 7 of the plant appendices, we describe any risk analyses that have been conducted by the vendor, the conclusions of those analyses, and the potential impact to the project schedules. While no detailed review of the risk analyses was performed to validate the vendor's assumptions, reviewing these analyses provides a better understanding of the thoroughness of each vendor's work and gives additional bases for our conclusions. No conclusions directly resulted from this review.

1.5 General Evaluation Approach

Based on the information obtained from the four NSSS vendors and the plant-specific evaluations performed for each vendor's plant, MPR performed a review of the schedules versus previous U.S. nuclear construction experience, a review of the general schedule assumptions made by all four vendors, and a review of areas that MPR considered to be insufficiently defined given the challenges associated with new nuclear plant construction.

1.5.1 Comparison with Past U.S. Nuclear Construction

The four construction schedules, from groundbreaking to commercial operation, were compared to information on past U.S. nuclear power plant construction experience. Section 2.1 describes the differences discovered in this comparison and their impact in the general shortening of the new plant construction schedules.

1.5.2 General Schedule Assumptions

The general assumptions impacting the construction schedules for the four plants are described in Section 2.2. These assumptions are broken into five categories: fundamental project assumptions, site-specific assumptions, engineering and procurement assumptions, construction assumptions, and licensing and permitting assumptions. The implications of these assumptions and their possible impact on the construction schedules were evaluated.

1.5.3 Insufficiently Defined Areas

Based on the reviews of the specific plant information as well as knowledge and experience from the nuclear industry, several insufficiently defined areas were discovered. These areas represent challenges to the plant vendors that must be overcome in order to fully develop the plant construction schedules.

2 Discussion

In order to evaluate the proposed schedules, a review of several industry issues was conducted. This section reviews details of past versus proposed U.S. nuclear construction, changes in project management strategies, the impact of modularization on construction schedules, a summary of new regulatory processes including schedule implications, and the possible impact and importance of assumptions.

The discussion presented in this section is applicable to all vendor schedules. Detailed evaluation of the impacts of these topics on specific plant schedules is included in the plant-specific appendices.

2.1 COMPARISON WITH PAST U.S. NUCLEAR CONSTRUCTION

This sub-section compares recently proposed nuclear power plant construction schedules and previously achieved U.S. nuclear construction schedules. We only considered schedules for plants that achieved commercial operation prior to 1979, in order to minimize the effects of the significant delays after the accident at Three Mile Island Unit 2 (TMI-2) in March of that year. These delays are considered atypical.

2.1.1 Comparison of Proposed Construction Schedules to Actual Schedules

One way to assess the proposed new nuclear plant construction schedule is to compare them to past actual schedules for completed plants. In the past, U.S. nuclear plants were generally built onsite, piece-by-piece with poured-in-place concrete. Buildings constructed using these techniques are commonly called “stick-built.” Since all currently proposed plants use modularization and advanced construction methods, comparison of the proposed to actual schedules provides an understanding of how these new methods will shorten schedules.

However, care must be taken in using actual schedules, especially for later U.S. plants, since they were constrained by regulatory delays in many cases. We consider the pre-1979 U.S. plant construction schedules to be the best basis for comparison to the newly proposed plants. Figure 2-1 shows the average nuclear power plant construction durations, from groundbreaking[5] to fuel load, between 1969 and 1977 (Reference 1.1). Note that 1977 was chosen because of the availability of information on construction durations through this year; it is considered representative of construction prior to 1979. The rapid increase in schedule durations during this period can be attributed to many factors, including: delayed completion of detailed design/engineering to support construction, increased complexity in designs, changes in

[5] Groundbreaking is defined as the start of site preparation activities.

regulations, labor disputes/strikes, construction problems, utilities' financing problems, and licensing delays. Some of the increase is also a result of the plants becoming larger over time.

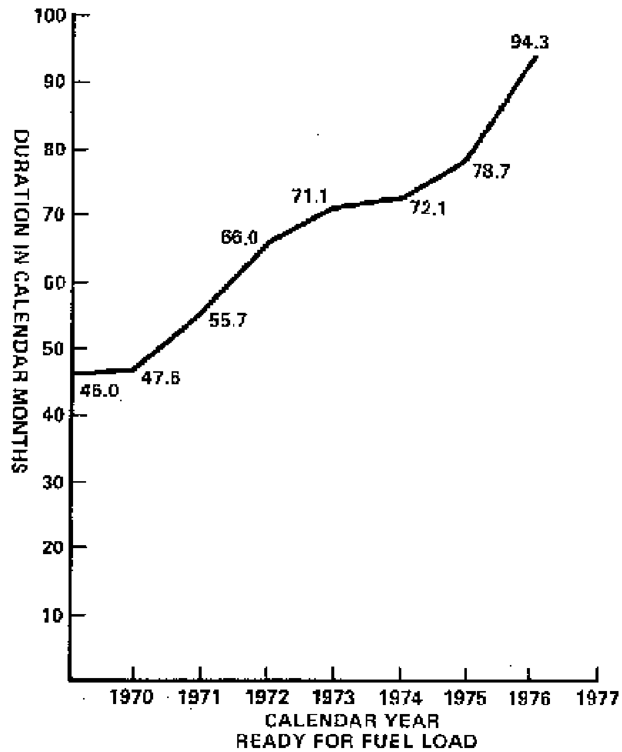

Figure 2-1. Average Duration for Past Nuclear Power Plant Construction 1969 to 1977

Schedule 'A' in Figure 2-2 shows the average on-site construction schedule for nuclear power plants constructed before 1977[6] (Reference 1.1). The average construction duration from groundbreaking to commercial operation was 79 months. Of the years surveyed, the shortest average construction schedule from groundbreaking to fuel load was 46 months which occurred in 1969.

Schedules 'B' through 'E' in Figure 2-2 are the proposed construction schedules for the four designs evaluated in this report. These schedules all show durations from groundbreaking to commercial operation of 60 months or less. The overall construction duration from groundbreaking to fuel loading for the new nuclear power plant designs is reduced by at least 19 months and by an average of 21 months. Proposed new plant designs have groundbreaking to fuel load schedules ranging from 48 to 54 months compared with the past average of 73 months[7].

[6] The average output of the 43 units surveyed in creating this schedule was 770 MW(e), which is less than most of the proposed plants discussed here. See Appendix E for more details on proposed plant outputs.
[7] 73 months is the sum of the 66-month average period between construction permit issuing and fuel loading from Reference 1.2 and the 7-month average period between construction start and actual construction permit issuing (which is a rounded average of 10 plants with information from References 1.3 and 1.4).

The 21-month average difference between the new and past plant schedules occurs during site preparation (before first concrete), and the construction phase (between first concrete and fuel loading). No changes in start-up durations are noted or expected.

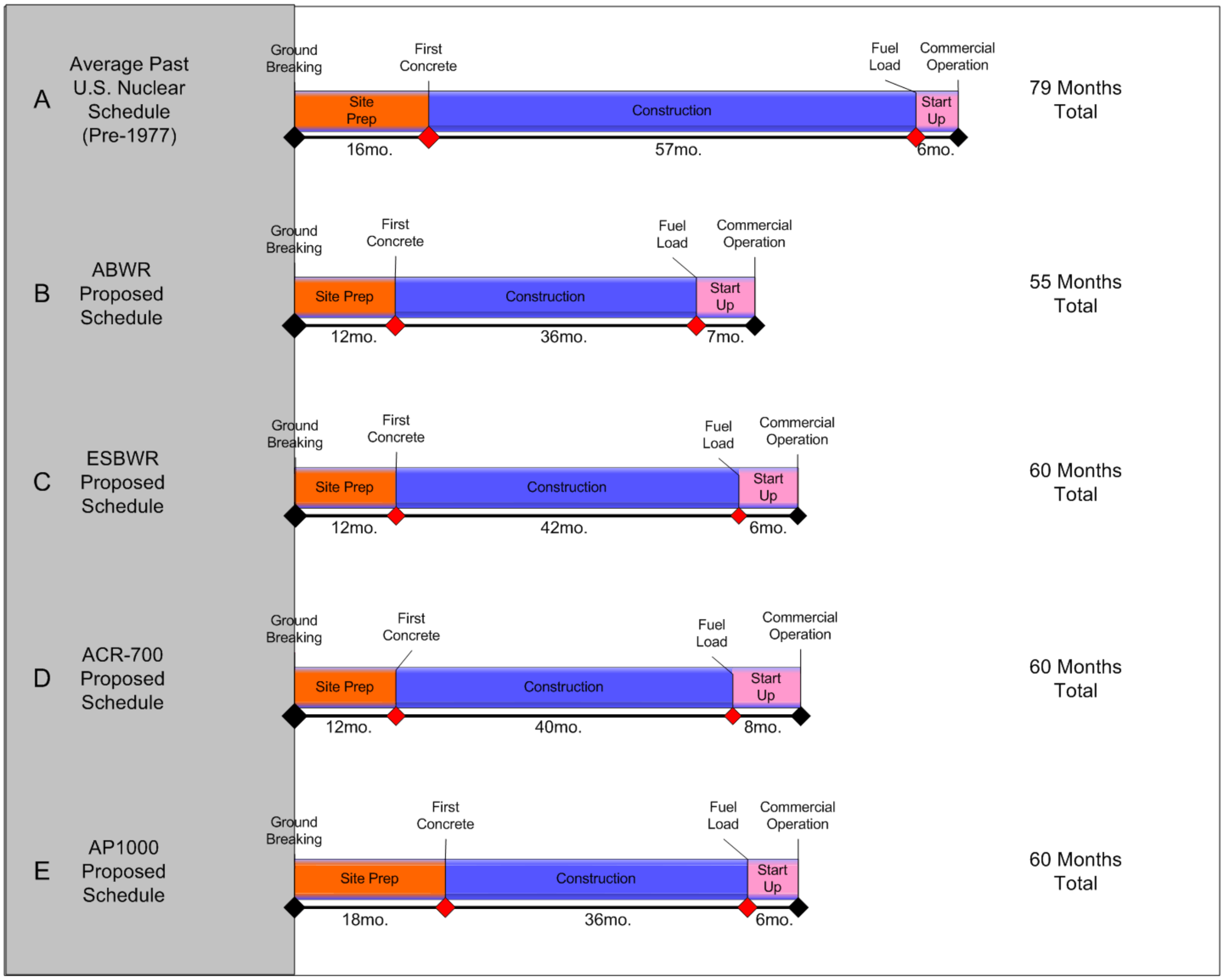

Figure 2-2. Past versus Proposed U.S. Nuclear Construction Milestone Schedules

Site Preparation Reductions

Research into past construction schedules indicates that site preparation activities typically began seven months before the construction permit was issued (see footnote 7 on previous page) and continued for an additional 9 months before the first structural concrete was poured. This results in a total site preparation schedule of 16 months. In comparison, the new plant site preparation schedules average 13.5 months for a difference of two and a half months.

This shortened duration may be attributed to the generally smaller site footprints used by the new plants as well as vendors anticipating using suitable sites. The vendors assume the sites have suitable geology as well as road, rail and utility access. Some vendors also assume barge access. Additionally, these sites could either already have operating nuclear reactors with additional land available nearby or are sites where construction was begun in the 1960s and 1970s, but was halted after the decline in demand for nuclear power in 1979. Both factors would reduce the overall time needed to prepare the site for pouring concrete. It is not believed that technological advances in excavating equipment could dramatically impact site preparation durations.

Construction Phase Reductions

The construction period between the first structural concrete pour and fuel loading is also reduced in new plant schedules. The average for previous plants was 57 months compared to an average of 38.5 months for the new plant schedules, a difference of 18.5 months.

These gains in schedule may primarily be attributed to the use of new construction techniques and technologies which allow for increased schedule efficiencies. These technologies include the use of modules to allow for off-site construction of parts of plant systems, open-top construction methodologies, and automatic rebar machines. The use of these new methods on non-nuclear projects has significantly shortened overall construction durations relative to past projects (Reference 1.8), and it is believed that they will have a similar impact on future nuclear projects. MPR-2610, "Application of Advanced Construction Methods to New Nuclear Power Plants" examines these methods and their impact on construction schedules in greater detail.

Startup Phase Similarities

One similarity between the past and current construction schedules is the time allotted between fuel loading and commercial operation. Both past and current schedules allocate about six months for this final phase. This appears to be a reasonable estimate as the final work to begin commercial operation in a new plant should be similar to the work that occurred in the past.

Shift of Work Load

In comparing predicted future schedules with past achieved schedules, it is important to note a shift in how events have been classified over time. Historically, the site preparation phase of a schedule included only those activities associated with preparing the land prior to pouring concrete. However, with the advent of modularization, many schedules now include the pre-assembly of large modules and rebar sections within the site preparation phase. Additionally, in past plant construction, concrete placements were not accomplished in long continuous pours as they are proposed in the evaluated schedules. Rather, concrete was placed in large sections. This difference means that the construction phase is now shorter because the long durations for rebar placement and formwork have been eliminated.

Distinctions such as these allow vendors to publicize shorter overall first concrete to fuel load schedules. First concrete placement to fuel load is often the time period first thought of with regard to construction durations, and it is advantageous for a vendor to make that duration as short as possible. Any activities that may begin during site preparation can be shifted away from this time. Less time performing construction activities on-site generally implies fewer overhead costs and less risk. By directing the work away from the site and thereby the time allotted for first concrete to fuel load, vendors are able to make a plant more attractive to potential investors.

2.1.2 Changes in Project Management Strategies

Over the last 25 years, advances in project management strategies and technologies have revolutionized the way large construction projects are approached.

Past nuclear projects often relied on separate design, procurement, management, and labor organizations to complete their phases sequentially, to produce a single product that was on-time, on-budget, and to the owner's satisfaction. These organizations had to overcome hurdles such as time, geography, and commercial concerns to communicate. More often than not, this translated into schedule delays and redundancies. Vendors proposing new plants recognize organizational concerns as the cause for these delays and are structuring their construction plans accordingly.

Teamwork from the beginning phases of the project design is considered critical to schedule success. The ideal construction team is comprised of designers, material vendors, operators, engineers, construction managers, and labor all focused under one umbrella organization with constant interactive regulatory participation. The team can establish a single contract with the owner, thereby minimizing the owner's risk to overall project completion and maximizing the probability for success by allowing the personnel with the most experience to manage the day-to-day affairs of the project. Subcontractors will naturally be employed by this organization, but they need to also be considered an integral part of the project team and feel ownership in the overall success of the project.

In an effort to additionally address the challenge of integrating the regulator into project development, the NRC has initiated the development of a Construction Inspection Program (CIP) and an associated Information Management System (CIPIMS). This system will allow the NRC inspectors to monitor the construction schedule and schedule inspections and ITAAC activities to mesh with the actual construction progress. This program is currently in development and will go through several trial runs to refine the process before it is implemented on a large scale.

Additionally, a coherent organization is necessary to obtain all the benefits of the new technologies being proposed. Modularization requires multidisciplinary thinking and a constant feedback process among designers, fabricators, and constructors to determine a) what needs to be built, b) if and how it can be built, and c) how it will be installed and made functional. When modules combine into systems, the team must furthermore consider how the technology is designed for the entire life-cycle of the plant. This includes design, installation, operation, and maintenance concerns.

A unified organization can also better use project management tools and technologies to communicate between personnel on-site and off-site. Single schedule tracking programs with integrated resource loading allow frequent updates of progress and close to "real time" updates for how critical path activities are proceeding. Effectively using software programs that can communicate amongst themselves is a proven means of increasing tracking efficiencies and identifying weak or lagging areas before they significantly impact the schedule. AECL demonstrated this capability on the Qinshan project by training all construction contractors to use the same software when planning, adjusting, and publishing schedules (Reference 4.2). AECL directly attributes completing the reactor ahead of schedule and under budget partially to an increased emphasis on teamwork and effective management communication strategies.

Centralized project management also increases the capability of project personnel to share information quickly. In the past, couriers and land lines had to be used to transmit drawings and details about problems in the field causing the loss of hours and sometimes days while information was en route. Modern technologies like shared network drives, cellular phones, and centralized display areas can reduce this transmittal time to minutes.

2.1.3 Impact of Modularization

Modularization promises to reduce construction schedule durations. Furthermore, of all the improvements that have been made in construction techniques, modularization appears to play the largest role in reducing each of the construction schedules. This section discusses requirements for the successful use of modularization, and its schedule benefits and risks. The proposed use of modularization in the various designs and the reliance on modularization to shorten construction durations are discussed for each plant in its respective appendix.

The use of modularization is closely related to two other aspects of new plant construction: the use of open-top construction techniques and a requirement for a large crane on-site during construction. Also, the transportation methods that are available at the construction site can affect the module design. The site should have good access to water, rail, and roads to make the most effective use of modularization.

The use of modularization places several requirements on the project schedule. Engineering design must be complete prior to module procurement. The schedule for component procurements will also be affected: materials required for modules will have to be ordered earlier than was necessary for conventional stick-built construction. Additionally, the use of multiple module vendors will require strict coordination to ensure proper delivery times. Finally, modularization will require a detailed plan for how to sequence and schedule connections between adjoining modules.

Modularization’s chief benefit is that it shortens schedules by:

- Creating parallel construction activities,
- Increasing the productivity of workers by allowing assembly in controlled shop environments as opposed to construction sites,
- Reducing work-site congestion so that on-site craft is more productive,
- Allowing construction of modules at grade and in easy-to-reach positions (e.g., vertical wall reinforcement constructed in horizontal position on ground),
- Removing/reducing the effects of weather at the construction site (if module assembly occurs at indoor facilities), and
- Reducing commissioning time of some equipment since testing may be conducted within the shop.

Modularization does introduce challenges to project schedules. These challenges include:

- Design schedules may increase because of additional up-front work,
- There is no prior experience in the U.S. with constructing a nuclear power plant using modularization[8],
- The number of domestic shops capable of performing module construction appears to be limited,
- The assumed benefits of modularization may not apply to FOAK plants and may not be realized until NOAK plants are constructed,
- In some cases the size and weight of large modules require that modules be delivered by barge to the site.
- Construction of temporary transportation infrastructure and laydown areas will be required during the site preparation phase to stage and move large modules once delivered onsite,
- Late delivery of modules can result in schedule delays and setbacks,
- Installation of modules must be highly structured and prioritized so connections can be made expeditiously,
- Damage to modules during shipment to the site has the potential to cause delays.
- Per Reference 1.7, the NRC is concerned about its internal resources and capabilities to inspect and approve modules within vendor shops or in the field prior to installation[9]. Inspections which are to occur after a module has been installed are expected to take longer.

2.1.4 Changes in the Licensing Process

In the past, the time required for NRC construction permit reviews between "Preliminary Safety Analysis Report" (PSAR) submittal and issuing of the construction permit ranged from one to four years, gradually increasing over time (i.e., 12 months in 1966 to 45 months in 1974, Reference 1.1). The average review duration was 21 months (Reference 1.1). These reviews were generally performed before most on-site work began (see Schedule 'A' of Figure 2-3). If the NRC determined that design changes were necessary, groundbreaking dates or the date of the first structural concrete pour could be delayed several years due to the time required to implement the changes. Additionally, plants had to account for the "ripple effects" that these changes had on the rest of the plant and its safety analyses. Changes could be required at any point in the review process, sometimes halting construction plans at the last minute.

The new generation of nuclear power plant designs will be operating under a new regulatory environment. The old process, which was used for the entire fleet of operating plants, is outlined in 10 CFR Part 50. This process included obtaining a Construction Permit (CP) and then an

[8] U.S. shipyards have experience building nuclear powered ships and submarines for the Navy using modular construction; however, the ship power plants (primary plants) are stick-built.

[9] The NRC staff is currently touring and examining overseas module fabrication facilities to understand when in the fabrication process inspections may be desired or necessary. Extensive planning will be required to implement the inspection plans.

Operating License (OL). The CP application included site details and a PSAR. The CP was granted before construction could begin and only included site characteristics and preliminary plant design information. The bulk of the design work for the plant was done during the construction phase of the project. Toward the end of the construction phase, the plant owner would apply for their OL. If any concerns warranting design changes were identified during the application review cycle by the NRC or the public, the modifications to the almost complete plant were costly and resulted in schedule delays.

As the industry matured in the mid-1970s, regulatory changes to address newly identified safety concerns had a major impact on the construction durations and project lifecycles. The duration to obtain an OL became even more uncertain after the accident at TMI-2 in 1979. At several of the most recently licensed plants, the process of obtaining the OL delayed the initial fuel load for years. An extreme case is Seabrook Station in New Hampshire. Construction began in August 1976, and an operating license was not issued by the NRC until March 1, 1990. The licensing delays were primarily caused by public concern and local authorities.

To address the impacts of these inefficiencies and the unpredictable nature of the licensing process, a new process was developed for the next generation of nuclear units. 10 CFR Part 52 was introduced in the late 1980's. "Part 52 is intended to make the process of licensing a nuclear power plant more predictable, more efficient, and more objective" (Reference 1.6, p. 2-18). The process provides more information about potential plant construction to the NRC and the public at an earlier stage. This is expected to minimize in-process modifications and make any required modifications less costly and simpler to implement.

Based on the estimates of NSSS vendors, the process of preparing, submitting, and receiving a COL is expected to take approximately 24 months, if an ESP and DC are in place, or up to 60 months, if an ESP and DC are not. However, this process has not yet been proven, and so these estimates cannot be evaluated. The regulatory process is being and will continue to be refined and developed as the first plants move through the new licensing steps. This learning curve for implementing the new licensing process may delay the schedule for the first new plants that move through the process.

In an attempt to maximize possible schedule gains from the new review process, some vendors are aggressively proposing site preparation efforts prior to COL issuance (Parallel Licensing Schedule - Schedule 'B' of Figure 2-3). This shortens the turnaround time between receiving the COL and pouring concrete, but exposes owners to the risk of design changes required by the NRC, which would lengthen the overall duration of the contract. The Pre-Application and DC processes should minimize these changes, but are not guaranteed to eliminate them. This is the path that is roughly presumed by the schedules for the ABWR, ACR-700, and AP1000.

A more conservative option is to wait until after the COL is received to begin site preparation activities (Series Licensing Schedule – Schedule 'C' of Figure 2-3). This schedule eliminates risk to the owner and other funding agencies by preventing any delays between the completion of site preparation and the beginning of construction. This is the path that is presumed by the schedule for the ESBWR, though proceeding with early site preparation is given as an option at the owner's risk.

At least for the first construction projects, the Series Licensing Schedule appears to be the one that is most likely to be followed by the future plant owner. Once the COL review process has been proven and better estimates are available for review duration, owners could then move toward advancing site preparation activities in parallel within their individual schedules.

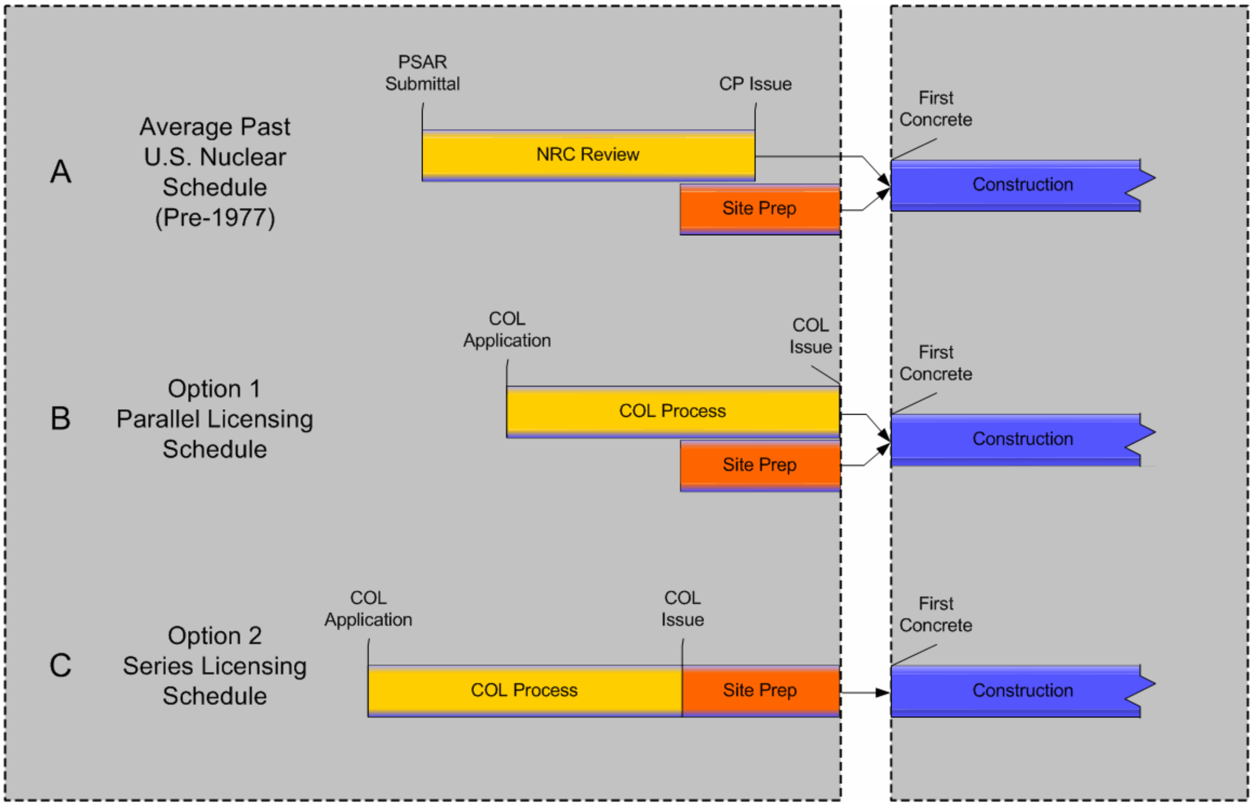

Figure 2-3. Potential Licensing Scenarios

A summary of the licensing process defined in 10 CFR 52 is provided below. This process consists of four main steps: design certification, early site permitting, issuance of a combined construction and operating license, and satisfaction of the plant defined inspections, tests, analysis, and acceptability criteria (ITAAC).

Design Certification

Design Certification is provided for in 10 CFR Part 52. DCs allow a standardized design to be pre-certified by the NRC for future use by a utility. The DC application must contain information describing the design and proposed ITAAC that are necessary and sufficient to ensure that a plant built to the DC and meeting the ITAAC will operate in accordance with the certification.

The DC allows generic nuclear plant design issues to be reviewed once for the standard design and not rehashed each time a new plant is licensed. When the utility decides to apply for a combined license or construction permit, they may reference the previously approved design certification for a standard design, therefore eliminating the need to review those items that have been closed in the DC. For each standard design, the rules governing additional review items are published as an appendix to 10 CFR Part 52.

There are three plant designs that currently hold DCs. These include ABWR, System 80+, and AP600. System 80+ has not been included in the schedule evaluation. AP1000 (an evolutionary successor to the AP600) is in the middle of the DC process and is nearing certification. ESBWR and ACR-700 are both in the pre-application phase of discussions with the NRC. Rules governing the design certifications for the ABWR, System 80+, and AP600 are provided in 10 CFR Part 52, Appendices A, B, and C, respectively.

Because DCs have been issued in the past, there is an understood process that must be undertaken to apply for DC. As an illustration of the regulatory schedule, the DC application for the AP1000 was submitted to the NRC in March 2002. The Design Certification approval is expected to be issued in December 2005. Improvements to this duration are possible because past DC reviews were conducted with no new plant on the horizon. Since the process is now more mature, there is little risk exposure to the construction of a new plant. Further, it is also very unlikely that a utility would commit the capital funds for a new plant to an NSSS vendor without a DC. In this study, we assume that any new plant will begin the construction process with a DC or will be very close to having a DC.

Early Site Permit Applications

Early Site Permits are another subject included in 10 CFR Part 52. An ESP may be applied for by a utility and then issued by the NRC. The ESP review process focuses on site safety, environmental protection, and site emergency response issues. The site safety issues include a description of the suitability of the site related to seismic, meteorological, hydrological, and geological characteristics. Any issues unique to the site that would cause an impediment to developing emergency plans must be identified.

This process provides approval of a site for one or more nuclear power plants without requiring the applicant to actually apply for approval to build a nuclear power plant yet. The site for the ESP could already have a currently operating NPP on it. Once the permit is granted, it is valid for between 10 and 20 years and can be renewed one time. This allows the applicant to "bank" a site and begin construction when the fiscal conditions in the marketplace are conducive. The concept of banking sites is new to the nuclear industry but is common in the fossil industry where sites are banked and construction is contingent upon winning a competitive bid to supply power in the region of the banked site. Banking sites also allows future modular nuclear designs of up to ten units per site to be built one unit at a time based upon economic conditions.

To vet the NRC's new ESP review process, DOE has matched funding with three major domestic nuclear generation companies to start the ESP application process. The lead sites to apply for an ESP are Dominion Power's North Anna, Virginia site; Entergy's Grand Gulf, Mississippi site; and Exelon's Clinton, Illinois site. For these initial applications, the NRC review schedule from application receipt to full commission approval is estimated to be three years. ESP approval for later projects is expected to be more efficient; however, the process is still likely to require approximately two years.

Combined Construction and Operating License

The combined construction and operating license in 10 CFR Part 52 is a significant departure from the old licensing process. A COL application must describe the design and the ITAAC that are necessary to ensure that the plant is constructed properly and will operate safely. A COL application may reference a DC, an ESP, both, or neither. All issues resolved during the proceedings of the standard DC review process or ESP review process are considered resolved except under narrow, clearly defined circumstances. Obviously, if a new plant is bypassing either the DC or ESP process, those proceedings would take place during the COL review process. As with the old 10 CFR Part 50 application process, financial information, anti-trust information, and an assessment of the need for power must accompany a COL application.

Some site preparation work and off-site fabrication of heavy equipment can begin prior to issuance of the COL; however, the process was developed so that any schedule risks due to licensing would be resolved prior to the bulk outlay of capital expenditures. Because of financial risk, it is unlikely that any significant amount construction will begin prior to issuance of a COL.

Currently, no utilities have begun the COL process. The process from submittal of an application until COL issuance is expected to take at least three years for the initial applications.

Inspections, Tests, Analysis, and Acceptance Criteria (ITAAC)

A COL authorizes construction and operation of a nuclear plant with conditions. Those conditions are described in the ITAAC that accompany the DC and the COL. ITAAC are those inspections, tests, analysis, and acceptance criteria that must be satisfied through NRC verification before a plant is authorized to load fuel and operate. In a significant departure from past plant licensing efforts, the selection of ITAAC during the design certification and COL process is heavily based on probabilistic risk assessments (PRA). In addition to the traditional safety-related and non-safety-related demarcation between systems, structures, and components (SSCs), an additional question of risk significance will be added to an SSC denoting its impact on measures like core melt frequency. Greater focus could be placed on safety-related SSCs with high risk significance. Additionally, safety-related SSCs with low risk significance would warrant less attention than non-safety SSCs with high risk significance.

The NRC will rely on the licensee to ensure that all ITAAC are satisfied. When the licensee has satisfied a given ITAAC, it will send the NRC a determination letter on that ITAAC. The NRC will verify that the licensee is in compliance with the ITAAC using sampling-type inspections.

The verification of the majority of ITAAC will be performed simply by comparing system performance measurements and observations against established criteria. Other ITAAC require verification over a longer period of time. The NRC has established a "Sign As You Go" (SAYGO) process to verify this type of ITAAC. SAYGO is a phased approach that reports the results of interim NRC inspections to the licensee. The SAYGO approach will reduce risk because the licensee is given feedback as to whether the long-term ITAAC is on track for acceptance during the entire construction phase.

2.2 GENERAL SCHEDULE ASSUMPTIONS

The schedules provided by the vendors are a compilation of assumptions about how the construction projects will proceed. Some of the assumptions made are based on information that is known with a high level of confidence. For instance, the assumptions made by Toshiba about the expected procurement lead time for the ABWR Reactor Vessel likely are realistic because they have recently procured vessels for their foreign construction projects. However, this type of historical data may not be available to justify other assumptions made by the vendors.

Table 2-1 shows a summary of the major assumptions made by the four NSSS vendors. Each line item in this table is discussed below with regard to how each assumption may impact the project schedule given the current status of the U.S. nuclear industry. Furthermore, "Additional Issues" are addressed to identify topics not explicitly addressed by the vendor.

2.2.1 Fundamental Project Assumptions

Before beginning to plan the construction of an NPP, some fundamental assumptions must be made about what type of project is being approached. A basic understanding of what is required to be built and what resources are available for use must underlie all other construction plans. The first section of Table 2-1 summarizes these fundamentals; their potential impacts are discussed below.

FOAK or NOAK

If a project schedule is assumed to be a NOAK project, then it is generally appropriate to assume that all engineering is complete and that vendor and subcontractor relationships are established. Engineering effort for NOAK projects will include lessons learned from previous projects to more effectively construct the plant. NOAK plants can apply something of an "off-the-shelf" mentality in seeking to achieve commercial operability. However, for a FOAK project, developing new techniques for construction and establishing relationships will be a significant effort and must be at the forefront of the vendor's thinking. More time will be required early in the project to establish infrastructure, and management must be diligent about the use and accountability of resources. Whether the vendor is proposing a FOAK or a NOAK plant is critical to understanding how time and resources are expended. Refer to Section 6 of each plant-specific appendix for discussion of how each NSSS vendor addresses FOAK vs. NOAK issues.

Licensing Prerequisites

The four plants analyzed here have demonstrated a basic understanding about the processes required to obtain DC, COL, and ESP. To make the most effective use of 10 CFR Part 52, vendors will have to work closely with the owners to make sure the necessary paperwork is completed on schedule and to the satisfaction of the regulator. Some site preparation work may begin prior to COL issuance; however, the potential unresolved issues represent a risk to the owner and to when the first concrete may be poured. Vendors and owners alike will also have to understand local permitting processes, especially at sites where operating units do not already exist. For additional discussion of licensing prerequisites, refer to Section 2.1.4 of this report.

Cash Flow

All of the vendors have made assumptions about the cash flow that will be available during the project. Particularly, initial required cash flow for all new construction projects will be highly accelerated when compared with the previous U.S. nuclear construction projects. In order to accelerate construction, particularly the on-site phase, early large cash expenditures are necessary to procure modules and long-lead items. This early expenditure should yield financial benefits resulting from shorter construction durations and quicker returns on the investment.

The assumptions made about cash flow are suitable for the purposes of initial scheduling. However, it is likely that investors will place limits on the amount of expenditures allowed early in the project. This is particularly true for investments that are assumed to occur prior to the receipt of COL for a FOAK plant. It seems unlikely that investors would be willing to take the significant additional risks by purchasing large components or hiring a large staff prior to the issue of the COL. Accordingly, there is potential for delay in the construction schedules as the vendors require additional planning, detailed engineering, hiring, and training activities following COL issuance.

Labor Availability

The amount of labor available to be dedicated to a site will impact the rate at which a plant may be constructed. This is especially true for skilled and nuclear certified labor. General construction and maintenance workers will be available from other industries for new nuclear construction and will not require extensive training. However, recruiting for some nuclear specialties (e.g., health physicists, radiation protection technicians, nuclear QA engineers/technicians, welders with nuclear certification, etc.) may be more difficult due to the limited number of qualified people within these fields. These difficulties may affect construction schedules depending on how many qualified workers can be recruited and the availability of these workers for scheduled activities.

This shortage of skilled workers in certain nuclear specialties may prove to be burdensome, especially if orders for new nuclear plants increase at a rapid pace. Due to the lack of new nuclear construction over the last 25 years, the population with nuclear expertise and training is dwindling and not replacing itself with new workers. Both technically skilled and craft organizations may require time to “catch up” with the industry and train an adequate number of personnel. Additionally, in order to have a sufficient number of workers on-site, the construction firm may need to investigate alternative labor options such as relocating skilled workers to a site for short durations to work around skilled labor shortages.

Labor Shift Structure

To evaluate the schedules provided by the vendors, it was necessary to understand what type of work shift schedules they had assumed. As shown in Table 2-1, this information was provided by all vendors except AECL. By using a 5-day-per-week, 10-hour-per-day schedule, Westinghouse has limited work to the most productive time of the day, and established a built-in contingency by allowing for an extended schedule of work on weekends and holidays to make up time if that should be necessary. However, this limits the number of personnel that are trained and knowledgeable about the project and site. The three shifts assumed by GE for the ABWR[10]

[10] See Footnote 1.

allow crews to efficiently work 7 days per week, but will force multiple turnovers within the schedule and the operation of some “skeleton crews” without the presence of a complete administrative staff. Further, this arrangement does not have any built-in allowance to make up lost time. GE has noted that the labor structure for the ESBWR will likely be different. Lessons regarding shift structure may be applied from previous major plant construction projects. Furthermore, labor functionality and productivity should increase with NOAK plants.

Labor Agreements

Organizing the construction of a new NPP may require coordination among several unions and an up-front understanding about how labor assignments will be made. The use of modules in a major construction project blurs historically understood roles and will require a systematic process for making sure work proceeds without major labor problems. Time must be set aside early to negotiate “no strike” language in labor contracts and to ensure that all parties involved are committed to the project’s success. Each of the vendors has made the assumption that this has taken place effectively prior to the start of work so that no delays due to labor difficulties are assumed.

Reference Location

Some vendors provided reference locations for their plants based on the ALWR URD, while others assume the use of pre-existing/designated NPP sites. The location of new NPPs will have a significant impact on schedule issues such as transportation (land vs. water accessibility), extent of site clearing and excavation required, and social receptivity to nuclear power. Excessive difficulty with any one of these factors may cause significant delays to the construction progress. As no ESPs have been issued at this time, both the vendor and future-owners must be aware of the role the physical locale can have in construction durations. Location selection will dictate the appropriateness of all site-specific assumptions listed in Section 2.2.2.

2.2.2 Site-Specific Assumptions

Once an ESP is obtained for a specific site, the vendor must fully examine the ramifications of all site-specific characteristics. The four designs being examined all make assumptions about what the site-specific characteristics are and how flexible the plant design can be in accommodating them. The second section of Table 2-1 summarizes some of the basic site specific assumptions; their potential impacts are discussed below.

Site Conditions

The condition of the land that will be used for new NPPs will dictate the amount of time required for site preparation activities (clearing, grubbing, cutting, filling, etc.). For pre-existing sites (with or without operating plants), the condition of the site should be relatively ready for construction activities. For brand-new sites, extensive research must be performed on soil and geologic conditions before reasonable estimates of time for site preparation activities can be calculated. The use of new land creates a potential risk for encountering site conditions that may impede construction progress.

Seismic Requirements
Design Certifications must specify a seismic envelope within which the plant must be qualified to operate. Typically, the envelopes developed by the plant engineering design teams attempt to meet most of the seismic spectra found through-out the continental U.S. However, some additional engineering may be required if the site-specific spectra exceed the envelope or if there are seismic caveats for certain pieces of equipment. This additional engineering, as well as the construction effort potentially required to support susceptible equipment, is a risk that may add time to the schedule. Plants with passive safety equipment are less susceptible to this risk since these designs typically involve less equipment (valves, pumps, etc.) that must meet safety-related seismic requirements; however, all plants must consider this on a location-by-location basis.

Accessibility/Transportation
One of the major site-specific assumptions made by the new plant designers is the transportation accessibility of the proposed site. Depending on the site, various means of transporting large, heavy modules and major plant components will have to be employed. The transportation methods used may limit the size and weight of certain modules or large components and can significantly affect scheduling of component transportation to the site.

For example, if the site is accessible by barge, much larger components can be shipped directly to the site compared with road or rail access. Barge-accessible sites would have the advantage of allowing more off-site construction and, therefore, greater use of large modules (providing they do not exceed the capabilities of the on-site cranes). Barge access may also be preferred for receiving large components from overseas manufacturers since this may reduce the need to transfer large components from barges to truck or rail.

2.2.3 Engineering and Procurement Assumptions

Along with site preparation decisions, the vendor must make assumptions about how engineering and procurement work will proceed. Topics such as the state of relationships with available vendors, the extent of engineering required post-COL, and durations required for the fabrication and procurement of long-lead items influence how the project will proceed from an early stage. The third section of Table 2-1 summarizes the vendors' engineering and procurement assumptions; their potential impacts are discussed below.

Engineering
For the four plants considered in this report, the amount of engineering that must be completed prior to the start of work far exceeds that which was required for previously built plants. All of these plants assume that most of this work will be done early and will not need to continue into the construction phase. Accordingly, schedule time is typically only provided for site-specific work. Completing and funding all other engineering work is a significant effort and is required prior to beginning the procurement of modules.

Procurement Relationships and Contracts
Considering that there has been roughly a 25-year dormancy period for new nuclear construction, few material vendors currently exist that have the expertise and capability to develop all of the new parts and equipment required for a new reactor. Relationships must be established on an

international level to ensure that commercial support is available for these large projects. Assumptions regarding the status of vendor/owner relationships and the state of contracts must be given significant consideration when determining appropriate durations for procurement activities.

The NRC is currently working with the Nuclear Procurement Issues Committee (NUPIC) to establish inspection and oversight criteria for potential nuclear vendors (Reference 1.7). These regulatory bodies must consider both introducing new vendors to nuclear quality assurance practices and ensuring that the quality requirements of international companies meet U.S. standards. See the discussion on “Foreign Vendors” below.

Long-Lead Components

Several items included in the new reactor designs require long fabrication times from approved vendors and additional time to reserve the necessary material. These include large items such as the RPV head and steam generators and small or bulk items such as nuclear-grade piping, pumps, and valves. Most NSSS vendors have performed research into lead times for some of these items, which enables them to make fairly accurate estimates. However, these durations should be confirmed during the final stages of preparation to ensure that the vendors’ capabilities and commitments still allow them to deliver items in the specified time.

Manufacturing Durations

As noted previously, manufacturing modules for use in nuclear power plants is an emerging industry. Based on previous work, some fabricators may be able to estimate the amount of time required for production of key equipment. However, the owner and construction manager should remember that these are just estimates with little or no experience to validate them. Fabricators, owners, construction managers, and NSSS vendors must closely coordinate their work in order to validate these assumptions.

Additional Issues

N-Stamp Qualified Vendors

The limited number of companies qualified to manufacture safety-related nuclear components will present a challenge for new nuclear plant construction. One sign of this limitation is the decline in the number of companies holding ASME N-stamps. In 1982 there were approximately 400 companies in the U. S. and Canada and an additional 70 overseas companies that held N-stamps (Reference 1.4). Currently there are only 43 companies that hold ASME N-stamps worldwide with 27 of these in the U.S. (Reference 1.9).

While N-stamps are not specifically required for the manufacture of safety-related nuclear components, N-stamp holding vendors are required to be used in some states. In addition, the number of companies holding N-stamps indicates the number of vendors that are currently producing safety-related nuclear components and are familiar with the quality assurance (QA) requirements. Companies will be more willing to invest in the efforts required to produce nuclear-grade components and to develop a nuclear QA program once new nuclear plant construction is assured. However, due to the cost and time required to develop these capabilities in non-nuclear vendors, the existing nuclear vendors will be vital in the initial new plant construction. The reduction of these suppliers from past levels calls into question whether current vendors will be able to accelerate production of components to meet new construction demand.

Foreign Vendors
The lack of qualified U.S. vendors of safety-related nuclear components will likely necessitate the use of overseas vendors for many components. While there has been no nuclear power plant construction in the U.S. for many years, vendors in Asia and Europe have recent experience in new nuclear plant construction and have many capabilities for construction of nuclear components that U.S. vendors have lost over the past 25 years. One of the challenges to making use of the skills and experience of these overseas vendors will be qualifying their processes for U.S. regulatory requirements and negotiating U.S. customs regulations. Qualifying these vendors for U.S. requirements in advance of nuclear component production may be a costly and time-consuming process that could significantly impact construction schedules. Note, however, that this effort has already been accomplished for large components such as RPV heads and Steam Generators, as these have been procured as replacements for the existing fleet. Smaller components will compose the bulk of the remaining effort.

2.2.4 Construction Assumptions

During the construction phase, vendors must consider how much modularization is being used, how realistic the installation schedules are, and what equipment will be necessary to complete the installation. The four designs under consideration use varying amounts of modularization and require specialized tools to implement their construction plans. The fourth section of Table 2-1 summarizes some of the vendors' assumptions regarding construction; their potential impacts are discussed below.

Extent of Modular Approach
Modularization is not a technique that has been used on nuclear construction projects in the U.S. Accordingly, attributing significant schedule reductions to its use poses a risk to overall construction durations. Vendors are aggressively using modules with the mindset that large blocks of work can be completed off-site and in-parallel with other tasks. On-site work should then be relatively straightforward. This optimistic mindset is fairly universal throughout the nuclear industry, but should be tested before it is relied upon too heavily. For more information on the impact of modularization, see Section 2.1.3 of this report.

Specialized Equipment
New construction techniques require the use of specialized equipment. Tools like VHL cranes and automated rebar machines may have to be ordered internationally and well in advance of any physical work. The coordination and availability of these tools may impact the amount of work that can be performed at any one time on the site. Their use will have to be precisely scheduled within the plant and their limited world-wide availability may restrict the number of plants that can be built at one time.

The open-top construction method used by the new plant designs requires a VHL crane to move large components and modules into the buildings. VHL cranes with the capacity, height, and reach required for nuclear plant construction are not currently available in the U.S. and would need to be procured from overseas.

Additionally, automatic rebar placing machines are used in some of the new plant designs and would also need to be procured from overseas (e.g., Japan). These custom-built automated rebar mat fabrication and detailing systems have been used on nuclear construction projects in other countries. The automated system uses CAD details to arrange straight or bent bars by placing them into a jig. The system vehicles move at right angles on a steel-frame support base to lay the rebar in a grid.

The procurement of this specialized equipment is important to the schedule assumptions of new plant designs and could significantly impact schedules if the equipment cannot be procured and shipped on-site before construction is scheduled to begin.

2.2.5 Licensing and Permitting Assumptions

How the regulator interacts with the plant owners and project management team during the construction process can facilitate or hinder the speed with which a plant can be completed. The four designs under consideration make broad assumptions about what role the NRC will play during construction and how rules and regulations may change with time. The fifth section of Table 2-1 summarizes some of the vendors' assumptions regarding licensing and permitting concerns; their potential impacts are discussed below.

Licensing Environment

As discussed in Section 2.1.4, changes in the regulatory environment are expected to be more conducive to safely and efficiently constructing new nuclear plants. Since the regulator and the vendor remain in the process of understanding how this process will be implemented, it was necessary for the proposed schedules to make assumptions about what sort of presence the regulator will have during construction (both on-site and off-site) and how that role may inhibit or facilitate progress.

2.3 PLANT SPECIFIC SCHEDULE ASSUMPTIONS

Table 2-1. Assumption Comparison Summary

Schedule Assumption Category	ABWR	ESBWR	ACR-700	AP1000
Fundamental Project Assumptions				
FOAK or NOAK	NOAK plant	FOAK plant	FOAK plant	NOAK plant
Licensing Prerequisites	COL required prior to first concrete. ESP is an option. If ESP is not obtained, a LWA is needed to begin site preparations. 27 months for COL review and 33 months for ESP review.	COL required prior to first structural concrete placement. ESP required prior to all site preparation work. COL application preparation, submittal, and approval could take more than 24 months.	ESP required prior to CED (i.e., prior to site preparation). COL required 12 months after CED (i.e., prior to pouring first concrete). COL approved 32 months after application submittal. Design Certification approved prior to COL.	ESP activities incorporated in the COL licensing process. 19 months are allotted for NRC review of the COL. This shorter duration for NOAK plants is attributed to portions of the application being "pre-approved" during FOAK reviews.
Cash Flow	No restrictions on cash flow to procure materials and components are expected.	No limitation on cash flow is expected.	No resource limitations were applied to the schedule.	No restrictions on cash flow (accelerated due to extensive modularization) expected.
Labor / Resource Availability	Required labor and other resources are available.	Required labor and other resources are available.	Required labor and other resources are available.	Required labor and other resources are available.
Labor Shift Structure	5/8 single shifts, with one additional shift on alternate Saturdays. Overtime work performed on critical path activities.	4/10 3-crew construction team. Work to proceed 7 days a week with each team working 4 days and taking 2 days off. Administrative staff on 5/8 shift.	Not Provided	5/10 single shift schedule. Limited use of second shift.
Labor Agreements	No extensive labor strikes assumed.	Labor agreements with "no strike" language to be agreed upon and signed prior to start of construction	Not Provided	Labor assignments negotiated and agreed upon prior to construction start. No strikes or labor delays.
Reference Location	U.S. location similar to K-6 site (e.g., Bellefonte Nuclear Plant site).	Kenosha, Wisconsin	Bellefonte Nuclear Plant site, Jackson County, Alabama	Kenosha, Wisconsin
Site-Specific Assumptions				
Site Conditions	Site is relatively flat with no major geological or topographical problems.	Site generally flat with open land. Good road access, construction power, telephone, and potable water supplies available within one mile.	Site will require minimal effort to clear and grade.	Site clear and level with no special problems. Site within 1 mile of highway access and 5 miles or less of railway access.

Schedule Assumption Category	ABWR	ESBWR	ACR-700	AP1000
Seismic Requirements	Seismic activity at site is within the reactor building and containment Safe Shutdown Earthquake envelope of up to 0.3g's.	Not Provided	Not Provided	Seismic Zone 1 – all design and construction techniques have been incorporated
Accessibility / Transportation	All shipping, handling, and preventative procedures have been incorporated based on experience from K-6/K-7 projects, which were located near the coast and allowed for barge transportation. The construction schedule assumes barge-accessible sites for large components, without special permitting for road/rail transportation.	All deliveries made by truck or rail.	Site accessible by water, either on the coast or on a navigable river.	All shipping, handling, and preventative maintenance criteria are established based on prior experience. All hold points are known and scheduled. Truck and train are the primary methods of transportation to the site. All bridges and roadways are capable of handling large and heavy loads.
Engineering/Procurement Assumptions				
Engineering	All engineering activities completed for K-6/K-7 plants. Specifications and bid documents already developed and available for future use.	All plant design and engineering, except site-specific engineering, will be complete prior to owner commitment to build the plant. Site-specific engineering should be complete in time to support site preparation. Engineering should not hinder procurement and construction activities.	Pre-project engineering will commence 12 months prior to CED. Design certification issued 3 months after CED. Release for Fabrication packages will be prepared and issued 12 months before start of fabrication.	A 100% certified plant design with all engineering complete and specifications and bid documents prepared in a computerized database from previous plant projects. Only site-specific engineering is required.
Procurement Relationships and Contracts	All procurement activities have sufficient lead time and funding to prevent delays. Pre-established international vendor relationships. New vendors selected locally, if needed, to reduce delivery times.	Contractual agreements will be developed to ensure that the correct materials and services are delivered on-time. Contacts with vendors made early and relationships well-established prior to initiating FOAK plant. Vendors available locally, if needed.	Material contracts for critical equipment are pre-negotiated. No purchase orders are issued prior to CED, although vendor evaluations and bid evaluations do proceed. Vendor relationships for key equipment based on experience from Qinshan project and discussions with prospective vendors. Pre-qualification of module fabricators complete in time to award major/critical modules at CED. Vendors available locally if needed.	A 30-day float time is built into all procurement activities. Key vendor relationships established based on previous plant projects. No pre-award vendor quality audits have to be performed to get any supplier on the ASL. Vendors available locally, if needed.

Schedule Assumption Category	ABWR	ESBWR	ACR-700	AP1000
Long-Lead Components	RPV, RCCV liner, and other long-lead items ordered during licensing phase and prior to start of on-site work.	Orders for long-lead items, such as those related to the reactor systems, will be placed 12 months prior to the Owner commitment to construct plant. Material reservations will be placed prior to fabrication orders.	Long delivery items (e.g., nuclear piping, pumps, and valves) are pre-ordered for critical modules. These are bulk ordered close to CED and delivered directly to the module fabricator.	Major equipment lead times quoted during the cost research by proposed nuclear vendors. Remaining lead times are estimated and need to be confirmed during final design. Long-lead equipment are ordered early using limited fund commitments prior to issue of COL.
Manufacturing Duration	Manufacturing durations for key equipment based on experience from K-6/K-7 projects.	Not Provided	Manufacturing durations for key equipment based on experience from Qinshan project and on discussions with prospective suppliers. Estimated duration for the fabrication of a module is 4 to 6 months, depending on complexity.	Manufacturing durations for major equipment based on quotes from proposed vendors.
Construction Assumptions				
Extent of Modular Approach	Moderate use of modules, especially very large site fabricated modules.	Extensive use of modules erected using a vertical open-top approach.	Extensive use of modules erected using a vertical open-top approach.	Modular approach integrated into the design from conception. Vertical open-top approach for Nuclear Island.
Specialized Equipment	Suitable VHL crane is available. Majority of welding and rebar work will be automated.	Open-top construction method suggests use of VHL crane. Rebar Placement Machine obtained from Japan, installed, and fully operational prior to beginning construction on Reactor Building and Reactor Building modules	Suitable VHL crane is available.	Lampson Heavy-Lift Crane and other cranes available
Licensing and Permitting Assumptions				
Licensing Environment	A stable nuclear regulatory environment is assumed.	Limited NRC presence on-site during construction (6-12 persons). NRC involvement pre-defined and agreed upon prior to beginning of construction.	Not Provided	A stable nuclear regulatory environment is assumed.

3 Conclusions and Recommendations

In general, we conclude that the construction portions of the schedules as presented by all four vendors are achievable. However, before the goals represented by these schedules can be met, the U.S. nuclear industry must overcome substantial challenges.

General conclusions and recommendations that are applicable to all plant designs and the U.S. nuclear industry are presented first, in Section 3. Plant-specific conclusions and recommendations are presented in Section 4.

3.1 STATUS OF THE INDUSTRY

The schedule evaluation revealed information about the status of some of the most promising reactor designs and their potential for near-term construction in the United States. Many conclusions from this evaluation are applicable to all of the schedules.

While the primary focus of this evaluation was on the construction schedules provided by the vendors, we believe that the overall amount of work remaining before construction of a new plant in the U.S. can begin is substantial and, because of various assumptions, has not been fully accounted for within the vendors' schedules.

The schedules each begin at various starting milestones and define pre-construction activities somewhat differently. These differences indicate that significant additional work is required before the U.S. nuclear industry will be ready to begin construction of one of these plants. A number of activities must take place prior to the start of site preparation. These include the resolution of open regulatory issues, the preparation, submittal, and review of Design Certification (DC), Early Site Permit (ESP), and COL applications, completion of FOAKE, detailed engineering and planning, and establishment of the plant owner and financial resources.

The overall construction project length proposed by each vendor is similar. However, some vendors have a head start when the entire project starting from today is considered. Based on the schedules provided and the pre-construction conditions that must be satisfied, it does not appear likely that any vendor could support commercial operation by 2010. Yet, with continued cooperative effort, achieving the goal of a new plant operation shortly after 2010 is feasible.

3.1.1 Overall Schedule Improvements

Compared with average nuclear construction schedules[11] previously achieved in the U.S., the proposed schedules show predicted schedule reductions of 29% (52 months on average versus 73 months from past experience) when evaluating the activities from groundbreaking to fuel load[12]. Using a slightly different measure, from first concrete to fuel load, the schedules are reduced by approximately 32% (38.5 months on average versus 57 months from past experience). These both project an improvement in overall schedule length. The reductions appear to be a result of two main factors: 1) assumptions about the new regulatory environment, and 2) the addition of new construction techniques that have shifted much of the labor from on-site to off-site construction of modules.

The difference seen between the two measures (i.e., groundbreaking to fuel load versus first concrete to fuel load) is also significant. It indicates that there has been a shift of work activities away from the period between first concrete to fuel load and into the site preparation phase. The shift allows the vendors to publicize short schedules for the highly visible first concrete to fuel load portion of the projects.

3.1.2 Project Management and Organizational Structures Impact

Contractual arrangements between owners, NSSS vendors, and architect engineers (A/Es) can affect many of the activities, durations, and logic within schedules. For the first plants built, these relationships may be complicated as the owner may consist of a consortium of utilities with some government cost sharing. A well-organized chain of command and well-developed decision making processes will be vital.

Details of the proposed organizational structures were not generally provided by the vendors. Therefore, it is unknown whether the appropriate organizational preparations are underway. However, a committed project team will be necessary long before the "contract effective date" (CED). The contract itself may define the project organization, but the CED referred to within some of the construction schedules must follow years of development engineering and planning. The preliminary contracts and relationships established now, possibly including government assistance, will develop into the organizations that will ultimately embark upon the construction projects. The business arrangements under which the projects are established will need to clearly define the chain of command as well as the project management responsibilities and priorities for all phases of the project.

Another challenge for the construction project organization is effective communication with the regulator. To achieve success with the proposed schedules, the regulator will need to be an integrated part of the project team, in constant communication with the owner. Previous construction projects in the U.S. have shown that difficulties with project organization and communication with the NRC have the potential to lengthen schedules significantly. The NRC's CIPIMS program is a significant step in addressing this challenge.

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[11] The past nuclear construction schedules that were surveyed were all prior to the accident at Three Mile Island and information on schedule durations was found in Reference 1.5.

[12] Refer to the discussion in Section 2.1.1 for additional details.

3.1.3 Modularization and Planning Impact

Extensive use of modularization has been proposed by each of the vendors. Modularization offers improvements to critical path construction schedules because work is able to be completed off-site. Effective and well-designed modularization will result in an overall reduction in the quantity of pipe, valves, hangers, etc., that must be installed on-site. This can be directly correlated to on-site schedule duration improvements. However, the use of modularization poses a challenge for initial construction projects. The following paragraphs describe the key challenges for implementing modular construction techniques.

Modularization requires an extremely high level of engineering and planning completion prior to construction, especially for a FOAK plant. Based on the schedule evaluations in the appendices, the vendors all appear to have a good grasp of this limitation and are working to plan appropriately. Because modularization will force engineering completion, it should also help to improve many of the planning inefficiencies that occurred on previous projects. For example, in the past, craftsmen often encountered problems such as hitting rebar within concrete when placing large pipe hangers. This un-planned problem required evaluation by engineering before the craftsmen could continue work, thus resulting in substantial lost time. Modern planning and engineering using 3-dimensional modeling of the “complete” plant can help to reduce the delay time caused by this type of difficulty and is required to ensure modules will fit together properly. NOAK plants will realize the most benefit from modular construction as problems with the fabrication and integration of modules in the FOAK plants are resolved.

The extensive use of modularization will place pressure on module fabricators to produce many modules within a very short timeframe. Multiple fabricators will be required to support the many modules necessary. While all of the proposed plants have all been designed with the use of modules in mind and the vendors have generally recognized the challenges associated with module fabrication, the vendors do not seem to have included the implications of the challenges of producing a large number of modules in their schedules.

The schedules provided by the vendors do not generally provide detailed information on the planning efforts that will allow their schedules to be achieved. We believe that the planning time required to support the use of modularization and other new construction techniques may require more time in the preparation phase than has been generally allotted by the vendors. Refer to Section 2.1.3 for a discussion on the potential impact and challenges associated with modularization on the overall construction schedules.

As this analysis was not focused on the details of plant and module designs, we did not attempt to determine the overall savings that could be attributed to each new construction technique. See MPR-2610, “Application of Advanced Construction Methods to New Nuclear Power Plants” for more information on other construction techniques that may improve schedule durations.

Since all of the new nuclear plant designs considered in this report propose using modularization in critical path activities success or failure of modularization construction techniques will significantly impact success of the projects.

3.1.4 Regulatory Impact

Great delays were encountered by constructors of nuclear power plants (NPPs) in the 1970s due to frequently changing regulations, public intervention, and NRC reviews that took place late in the construction process. To improve the regulatory environment for the next plants to be built in the U.S., the NRC has established a new regulatory process. This regulation is described in 10 CFR Part 52. The process was designed to make the licensing of a NPP more stable and predictable by moving much of the decision-making process forward so that all major questions must be answered prior to start of plant construction.

The proposed schedules each assume that the regulatory process will work as designed, thereby eliminating construction delays from emergent regulatory activities. However, based on the review in the plant appendices, none of the schedules contains a contingency for process implementation challenges. This is an area of risk because the new process remains untested and will be refined as the first plants move into the licensing process. For the first plants constructed, we expect regulatory involvement to impact the overall schedules as the process is initially implemented.

3.2 CONCLUSIONS ABOUT GENERAL ASSUMPTIONS

Project schedules are developed by making assumptions. While any assumption has the potential to affect the overall schedule, some key assumptions are of interest.

In Section 2.2, the assumptions made by each vendor are compared and discussed. Although each schedule was found to be generally complete and reasonable with respect to the given assumptions, some of the assumptions do not appear to accurately represent the readiness of the U.S. nuclear market. This is especially true when considering FOAK projects, which are the basis for many of our comments.

3.2.1 Fundamental Project Assumptions

FOAK or NOAK

Each vendor chose to prepare either an NOAK or FOAK schedule. This choice affects virtually all other aspects of the schedule. In particular, NOAK schedules are good at presenting the anticipated efficiencies that can be achieved with later plants, but do not lend confidence that the vendors will be able to achieve their proposed FOAK schedules. The plant-specific conclusions in Section 4 discuss this observation in more depth. It is important for the industry to understand the bases for the estimated schedules and to maintain a firm grasp on the activities that will be required to support the first and the subsequent plants. To realize the NOAK benefits, consortia of future owners who are willing to build multiple plants and share lessons learned will be necessary.

Licensing Prerequisites

The differences between the COL review periods and other licensing activities in the vendor schedules highlight that the industry remains unsure of COL application requirements and the length of time the licensing process will take. Additionally, assumptions about the duration of the ESP process are varied between the schedules.

These assumptions are likely to impact project schedules significantly. It appears unlikely that owners will be willing to take on the risks of carrying out licensing in parallel with procurements and extensive site preparation work. As the licensing process is not yet proven and the vendors and owners cannot assume that the process will initially function in a wholly predictable manner, it is considered judicious for vendors and owners to proceed cautiously in scheduling dates for licensing activities.

Cash Flow

Cash flow is assumed to be an unlimited resource within each schedule and is a key requirement to achieve short construction schedules. Utilities and investors will ultimately need to decide whether the tradeoff between large early expenditures is countered by short schedules and early commercial operation. Changes to the plant design that may result from licensing activities could lead to rework. Early purchases, particularly those prior to the issuance of a COL are made at-risk to the owners.

Labor/Resource Availability

Unlimited quantities of skilled labor are assumed to be readily available near the construction sites. However, labor availability in nuclear-specific fields has been dwindling in the U.S. over the last several decades. Finding qualified labor may be a significant hurdle for new construction projects, especially if multiple plants are being constructed. The use of modularization may alleviate this problem somewhat by allowing work on large sections of the plant to be performed at many locations simultaneously. However, as with any construction project of the scale of a new nuclear power plant, finding and relocating the labor required to complete the project will be a major challenge.

Resources (e.g. personnel, equipment, materials) were assumed non-limiting in each of the vendor schedules. As the availability of resources often drives schedules, this assumption is likely not accurate.

Another potential limitation on the schedules is the rate at which materials (e.g., concrete, piping, electrical cables) can be installed. Installation rates were not available for most schedules; therefore, the extent of the impact was not evaluated.

Labor Shift Structure

Tradeoffs between the number of shifts, the number of people that require training for the project, the availability of management oversight, and the allowance for contingencies in the schedule are made in each structure. A shift structure that allows for more management oversight and greater contingencies for delays would be preferred from a schedule maintenance point of view. However, labor availability and construction cost concerns also play a large part in deciding upon the most advantageous shift structure.

While labor shift structures vary among the four proposed plants, all presented labor shift structures are reasonable and do not pose a significant risk to the construction schedules.

Labor Agreements
Each vendor has discounted the possibility of work stoppages due to strikes or other labor problems. We consider this assumption to be reasonable and should not constitute a major risk to the schedules. With appropriate planning and up-front labor agreements, work should be able to proceed as scheduled.

Reference Location
The location of new NPPs will have a significant impact on schedule issues such as transportation (land vs. water accessibility), extent of site clearing and excavation required, and social receptivity to nuclear power. Excessive difficulty with any one of these factors may cause significant delays to the construction progress.

3.2.2 Site-Specific Assumptions

Assumptions were made by each vendor regarding the conditions at their chosen plant site. The assumptions made were different in each case (with the exception of AP1000 and ESBWR which use the ALWR Utility Requirements Document (URD) requirements for site conditions), limiting the general impact of these assumptions. However, note that site-specific assumptions impact schedule durations significantly.

Site Conditions
All four proposed plants assume that the plant site will require minimal effort to clear and grade, have no special geological, topographical, or environmental problems, and is readily accessible by road, rail, and, in some cases barge. Site conditions other than these near ideal conditions could have significant impacts on construction schedules as unforeseen problems delay early site preparation activities.

Seismic Requirements
The proposed plants that list seismic requirements generally assume that they are relatively mild. Locating a plant in an area with high seismic requirements could result in significant delays due to required re-analysis of the plants seismic response and equipment design.

Accessibility/Transportation
The importance of plant site accessibility has increased significantly due to the use of large modules and large preassembled plant components that have special transportation requirements. For example, if a site is water accessible, then very large modules may be transported to the site intact, while if road and rail are the only means of transportation to the site, then on-site assembly of modules is required.

Changes to the assumptions made regarding site accessibility and transportation of major components can have a major impact on planned construction schedules as alternate plans for the delivery of large modules must be developed.

3.2.3 Engineering and Procurement Assumptions

Engineering

All vendors assume that the majority of engineering work will be completed prior to any physical work. All vendors currently have a gap between the status of the engineering that is completed and the status that is assumed at the start of their schedules. Closing this gap will require a significant effort on the part of vendors and constructors.

Procurement Relationships and Contracts

NSSS vendors must establish relationships with component and module vendors. The schedules generally assume that these relationships will be in place very early. This is a reasonable starting point for schedule development. Yet, efforts to locate and establish relationships with vendors, particularly those for module fabrication, take time. Even those vendors who have built plants recently face this challenge, as U.S. component and module vendors are more limited than in foreign markets. In general, we consider that additional time will be required to establish relationships with vendors than has been allowed for within the vendor schedules.

The first plants to be constructed are likely to require significant use of foreign vendors. The schedules supplied by the vendors do not address extended procurement durations that may be necessary to qualify suppliers on U.S. regulatory requirements or to deal with customs issues.

Long-Lead Components

NSSS vendors have performed research into lead times for some of these items, which enables them to make fairly accurate estimates. However, these durations should be confirmed during the final stages of preparation to ensure that the vendors' capabilities and commitments still allow them to deliver items in the specified time.

Manufacturing Durations

The use of modules in nuclear power plant construction is an unproven process that is still under development. Therefore, fabricators, owners, construction managers, and NSSS vendors must work closely to validate schedule assumptions made regarding equipment manufacturing durations.

3.2.4 Construction Assumptions

Extent of Modular Approach

The vendors of the four proposed plants are aggressively using modules to complete large portions of the plant construction offsite in parallel with onsite work through the use of modules. Although this approach has been used successfully overseas, it has yet to be fully tested in the U.S. The challenges of coordinating module vendors with the overall plant construction are significant and success in these challenges will be very important to the realization of the proposed construction schedules.

Specialized Equipment

The use of new construction technologies to decrease construction schedules requires specialized equipment such as Very Heavy Lift (VHL) cranes and the automated rebar machines to be available early in the construction process. However, there are limited quantities of those tools in the world. Locating, purchasing, and shipping equipment to site may be challenging within the timeframe that is allotted.

In addition to the availability of the equipment itself, labor forces must be trained to use the tools. This is not included in the vendors' currently identified project scope.

3.2.5 Licensing and Permitting Assumptions

Licensing Environment

Vendors assume the new regulatory processes in 10 CFR Part 52 will provide a stable environment for construction. This is reasonable for initial planning, but many hurdles are likely for the first plants. The vendors generally assume that licensing activities may be scheduled such that the possibility of schedule delays due to regulator impacts is eliminated. While the NRC is working towards this goal through their CIP program, assuming no licensing impact is ambitious even for NOAK plants and should be examined closely.

Because of the uncertainty involved in the licensing process (see Section 2.1.4), it is not clear how much effort an owner would be willing to invest before important milestones such as ESP, DC, and COL have been achieved. Schedule logic may have to be adjusted to mitigate licensing risks.

Additionally, licensing uncertainty is a construction risk because some licensing milestones are predecessors to construction phases. Specifically, an ESP (or Limited Work Authorization [LWA]) is required before site preparation, and a COL is required before first concrete. As these activities are both on the critical path, any delays in achieving the licensing milestones will have a direct impact on the construction schedules.

Inspection, tests, analysis, and acceptance criteria (ITAAC) have potential to affect plant construction schedule in three ways. First, ITAAC defined during the COL process are not currently well understood. Efforts undertaken by the NRC and industry to define what ITAAC are appropriate at the COL stage are ongoing and unresolved. Therefore, it is possible that ITAAC developed during COL will require activities that are unanticipated in project schedules. Second, closure of ITAAC prior to fuel load is the final point in the regulatory process where the public can intervene. Any opportunity for public intervention raises the risk of schedule delays. Third, if ITAAC inspections of components at vendor sites fail, project personnel will need to closely monitor the situation and make contingencies for the delays this may produce. Vendor sites overseas or in otherwise remote locations may add to the challenges of resolving failed ITAAC for critical components. However, by clearly defining ITAAC early, this risk can be alleviated.

3.3 INSUFFICIENTLY DEFINED AREAS

Several areas within the schedules were weakly defined. The detailed evaluation performed in the appendices, along with knowledge and experiences within the nuclear industry have led to the conclusions presented in this section.

First-of-a-Kind Engineering

FOAKE activities remain for the reviewed plant designs (with the possible exception of ABWR[13]). This work must be completed prior to construction. FOAKE activities could result in design changes that may affect the construction schedules. As the level of design completion increases, the degree of confidence in construction schedules will also increase.

Remaining FOAKE was not evaluated for this report.

Procedures and Training

There is a low level of confidence that the vendors have fully identified the activities required for procedure development (only Westinghouse provided information on procedure development and this was generally at a high level). Procedures for operation of the NPPs need to be specific to the final configuration of the plants. In addition, they are often defined by the owner in collaboration with the NSSS vendor. We understand that preparing detailed procedures prior to issue of COL is a financial risk that some owners may be hesitant to undertake. However, since plant configuration is not yet fully defined, especially with regard to the primary operator system interfaces of the plants' digital controls, the scope of procedures is unknown. (See below for a discussion of the development of the digital controls on the construction schedules). Further review will be required to determine whether there is sufficient time within the schedules to allow for detailed procedure development following COL.

Plant operating personnel will be required to support system testing and qualification activities. These activities begin early in construction as systems are completed. Training programs must be developed and implemented for the operators in time to support system testing. In general, these have been weakly defined or omitted from the vendors' schedules.

Operator training activities on the simulator have also been weakly defined within all of the vendor schedules. Only GE provided a schedule for the development and construction of a simulator. It is likely that their basis for this information is their recent experience with simulator construction for the ABWR at Lungmen, Taiwan. For FOAK plants, simulator construction could be on the critical path because of the need for early availability to support operator training. (See the following section for further discussion of simulator development.) Because of the potential impact to the critical path, it is important that vendors define training activities to a greater level of detail.

Digital Controls and Simulator

Vendors advertise the use of digital control technology throughout their new reactor designs to allow for greater automation and control. Vendors have prepared conceptual designs for those systems, but have not initiated detailed designs for U.S. plants. The DCs issued so far have deferred review of the main control room (MCR) and digital controls until the COL stage. This is largely because the vendors want to be able to offer the most up-to-date systems at the time of the plant purchases.

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[13] The Toshiba ABWR has been excluded from the NP2010 FOAKE evaluation because operational plants already exist. The deployment of a Toshiba ABWR in the U.S. may require some changes to the designs constructed previously (i.e., to meet the specific requirements for nuclear plant operation within the U.S. and to satisfy any new commercial improvements) however changes would be considered site specific design features.

Recent controls upgrades in the existing fleet have shown that significant regulatory hurdles must be overcome before implementing digital controls concepts. The U.S. regulatory guidance on the design of advance control rooms is largely untested. The full scope and complexity of implementing digital control systems is not yet understood.

NPPs must have a plant simulator for training purposes. With the exception of the GE ESBWR, simulator development and construction activities are generally not well-defined within the vendor schedules. This omission could impact the ability to train operators in time for plant start-up activities. See the discussion about training, above.

Even in NOAK plant projects, where the detailed design for the simulator may be available from previous projects, human factors design may need to be revisited to meet any specific utility standardization requirements (e.g., requirements for displays, colors, etc.). Both the simulator and MCR design will need to be revised and adapted to meet any special utility requirements.

To achieve the proposed construction schedules, gaps in both the design maturity and regulatory guidance for digital controls and simulators must be bridged. This development will likely require several years prior to equipment procurements. Depending on when the first order for a new plant is placed, the development and testing associated with new digital instrumentation and controls could be the limiting engineering activities for the next generation of nuclear plants.

3.4 General Recommendations

Our recommendations to facilitate the goal of a new nuclear plant operating in the 2010 timeframe are summarized in Table 3-1, below. Table 3-1 also notes the relationship between these recommendations and initiatives under way or planned by DOE or other government or industry groups. If there is no initiative that addresses the recommendation or activities in progress do not completely address the recommendation, additional actions to implement the recommendation are described. Recommendations specific to each reactor design are in Section 4 of this report.

Table 3-1. Summary of General Recommendations and Action in Progress

General Recommendation Number[1]	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR1	Work needed to prepare for construction (such as preparation of COL applications and obtaining NRC approval, establishment of project team organization, establishment of financing, etc.) must have few or no outstanding issues remaining at construction start to enable construction teams to accomplish the short construction schedules planned.	DOE and industry should closely examine those activities that must occur prior to the start of construction and provide the resources and financial support required to complete them.	DOE has issued a solicitation for a COL Demonstration Project to test the COL process by obtaining a COL license from the NRC. It is expected that the nuclear industry team in this project will also develop detailed plans to accomplish preparations for construction of a plant. The DOE / Nuclear Power Industry Strategic Plan for Light Water Reactor Research and Development, February 2004, ("DOE/Industry Strategic Plan") also addresses many of the steps necessary for construction of a new plant.	None.

General Recommendation Number[1]	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR2	See finding for GR1 above.	DOE and industry should continue efforts to submit COL applications. As progress is made, schedule estimates should be updated to reflect new information. Scenarios of licensing schedules for both FOAK and NOAK plants should be reviewed to address acceptable risk prior to COL issuance.	Under a DOE / Industry cost-shared project, NEI is developing a COL Application Guidance document (NEI 04-01 document) to assist power companies in preparing COL applications. This document is planned to be provided to the NRC for review and comment in December 2004. The DOE COL Demonstration Project will result in an owner-vendor-constructor team submitting a COL application.	It is expected that vendors and potential owners will update overall project schedules based on actual time to prepare and obtain COL, extent of ITAAC developed, and actual business arrangements planned. Also, potential owners should review actual time to obtain COL and work with NRC to streamline the COL process for NOAK plants.

General Recommendation Number[1]	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR3	Although the NRC identifies some Inspections, Tests, Analyses and Acceptance Criteria (ITAAC) during the Design Certification (DC) process, the complete list of ITAAC will not be available until a COL application is prepared and approved by the NRC. The schedules reviewed omitted or only roughly outlined ITAAC activities.	No *general* increase in construction schedule float is recommended to address uncertainty with regard to ITAAC within the construction phase of the project schedules. As the regulator further defines ITAAC, vendors should define the detailed activities within their schedules that will be required to support ITAAC resolution. As plans progress for FOAK plants, vendors should update their schedules to incorporate the most realistic and accurate estimates of the schedule impact of regulator inspections and other activities.	DOE / Industry Strategic Plan Statement of Work (SOW) for Objective 1-1 includes a demonstration project to assure "ITAAC verification can support an aggressive construction schedule." NRC and Westinghouse are performing an ITAAC Pilot Project to exercise the vendor/NRC interaction by treating a major equipment project (such as SG replacements) as a new construction project and exercising the ITAAC process.	Vendors and constructors should insert ITAAC inspections and preparation into schedules and incorporate results of development of the ITAAC and NRC Construction Inspection Program processes in project schedules with effort and durations based on the outcome of ITAAC demonstration projects by NRC and DOE and ITAAC definition efforts by NEI and NRC.
GR4	Schedules vary in the level of detail and preparation regarding steps needed to obtain COL license and a plant construction contract. Some assumptions regarding the level of effort and timetable for these steps are not well-supported.	Industry should develop an all-inclusive list of remaining activities required for FOAK plants. This will help to focus near-term support for remaining technical and programmatic activities.	The COL Demonstration Project will also define remaining engineering and detail design activities. It is expected that vendors will continue to assess design certification and COL licensing efforts as well as the activities for detailed plant design necessary for FOAK plant licensing and construction.	None.

General Recommendation Number[1]	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR5	Plant project team structure (minimal or zero changes by owner after order, rigid assignment of authority for decision-making, high pre-construction level of effort, etc.) must be different from previous projects to support achievement of the shorter construction schedules.	Vendors, utilities, and potential investors should evaluate the options for organizational and project management structures that will be best suited to the construction of a new nuclear power plant. These structures should include contractual arrangements and a detailed chain-of-command for various decision making processes.	Vendors and utilities are teaming to respond to the DOE COL Demonstration Project solicitation. Some aspects of these teaming agreements should be applicable to a contractual arrangement leading to plant construction. It is expected that vendors and utilities are evaluating options for project structures for new plant construction as part of contract arrangements for an actual order.	None.

General Recommendation Number[1]	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR6	Each vendor assumed that cash flow would be available as needed to support completion of engineering and the procurement of long-lead items. The need for a high level of design completion and funding of pre-fabrication of modules and long-lead time items to facilitate modular construction and reduced on-site construction time will alter the pattern of cash flow needed to fund future projects relative to previous nuclear plant construction projects.	A group of utilities considering constructing a new plant should investigate potential limits that will be placed on cash available to fund activities early in new nuclear construction projects. Also, this group should address what investment risks the industry believes it would be willing to take with respect to beginning long-lead item procurement and site preparation prior to the issue of COL.	None.	As potential owners, constructors, and vendors proceed towards establishing a project structure and contractual arrangement for plant construction, they will have to incorporate the effect of cash flow limitations into the project schedule.

General Recommendation Number[1]	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR7	Present schedules do not address man-loading or labor availability. Labor availability will lengthen the construction schedule if shortages of critical skilled crafts reduce the number of shifts or man-hours that can be applied to construction activities.	While it is difficult to predict labor availabilities without first identifying the plant location and timeline for construction, the industry should evaluate the labor availability near possible plant sites. Additionally, vendors and constructors should use this data to modify the schedules to balance resource availability and schedule length.	DOE / Industry Strategic Plan Statement of Work (SOW) for Objective 1-4 includes an assessment of "adequacy of nuclear training pipeline and skilled construction trade sector to support near-term deployment." Vendors and constructors are planning to assess the construction trade sector in the regions of early site permit applications or where there is utility interest in construction.	DOE should assess the construction infrastructure required to restart building of new nuclear plants in the U.S. and compare this to the available infrastructure, then analyze the timetable for industry actions needed to make up shortfalls. This assessment should be disseminated to make industry aware of the lead time to have needed infrastructure available at construction start.
GR8	Significant FOAKE activities remain for three of the reactor designs. Ongoing engineering can result in design changes that could impact schedules. It is critical to identify changes early in order to reduce their impact on the schedule.	An ongoing NP2010 effort to identify remaining FOAKE work is an important step toward achieving the necessary level of engineering completion. Detailed engineering activities needed to support COL applications and construction should be completed by the vendors in the near term. DOE should consider cost sharing assistance for vendors to complete these activities.	DOE COL Demonstration Project will advance the engineering completion of the reactor designs involved as needed to support obtaining a COL. Also, DOE / Industry Strategic Plan SOW for Objective 1-2 includes design completion of "near-term Generation III+ designs that industry is willing to consider for a plant order."	It is expected that vendors and architect/engineers will identify changes to construction schedules required by the detailed design and licensing process and will ensure these are analyzed promptly to reduce risk of schedule increase.

General Recommendation Number[1]	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR9	Operator training and procedure preparation activities are generally omitted or loosely defined within the vendor schedules. This includes the development, construction and use of a plant simulator. These activities could impact critical path.	Vendors and utilities should prepare plans for training activities that will be required prior to operation of the new NPPs. The plans should then be integrated into the existing schedules to reveal impacts to both FOAK and NOAK construction schedules.	None.	It is expected that vendors will determine the required effort to develop training plans needed to support testing, commissioning, and operation of a Gen III+ plant. The resources required to carry out training and integrate the training timeline into the construction schedules will then be included.
GR10	Digital control systems and control room simulators are untried in the U.S. regulatory environment, and Gen III+ design certifications defer definition of the I&C system to the COL application phase. The schedule risk posed by delays in design and licensing of digital control systems is significant.	Additional development is necessary by all vendors to define the design, licensing, procurement, construction, and testing activities related to digital controls and simulators for the new NPPs. This should include discussions with the NRC about the requirements that will be used to review the digital control and the simulator designs to ensure that regulator expectations will be met.	DOE / Industry Strategic Plan SOW for Objective 2-1 includes completion of FOAKE for Generation III+ plants, to include design of digital equipment. The COL Demonstration Project should result in definition of the digital I&C design and the licensing approaches for the plant(s) involved, as well as a COL that licenses that design.	It is expected that NSSS vendors will perform sufficient design of the digital I&C systems for COL applications to result in licensing by the NRC, and that the approach to completing the I&C system detail design will support early resolution of issues to avoid plant construction or commissioning delays.

General Recommendation Number[1]	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR11	Each vendor assumed that relationships with component supply vendors would be established in a timely fashion. To enable the proposed schedules, these relationships must ensure that components can be delivered within the constraints of the critical path.	Component vendor relationships should begin to be established by vendor and constructor teams as soon as possible. Early detailed engineering efforts should be coordinated with the fabricators to ensure that the designs are constructible and can be delivered to support the construction schedule.	DOE / Industry Strategic Plan SOW for Objective 1-4 includes an assessment of fabrication/manufacturing infrastructure for specialized equipment and is meant to identify sources for all major nuclear plant systems and components. NSSS vendors are working to locate sub-suppliers for required equipment.	It is expected that NSSS vendors will give sufficient priority to the establishment of plant equipment procurement plans to support the construction schedule.
GR12	A significant portion of plant equipment is expected to be fabricated outside the U.S. Although large special equipment such as steam generators and RPV heads are imported now, the increased volume and scale of importation for new plants could be a QA and logistical challenge to the schedules.	The NSSS vendors and constructors should review the policies and requirements that are imposed on foreign-manufactured or safety-related equipment and determine the extent of the schedule impact of developing quality programs, especially by smaller component vendors. Also, the effect of potential customs and shipping delays on the schedules should be reviewed.	DOE / Industry Strategic Plan SOW for Objective 1-4 includes an assessment of fabrication/manufacturing infrastructure for specialized equipment and is meant to identify sources for all major nuclear plant systems and components. NSSS vendors are in the process of identifying sub-suppliers for major components.	It is expected that NSSS vendors will work with sub-suppliers to establish QA processes that ensure equipment meets requirements, to verify supply chains will support the aggressive construction schedules, and to plan the coordination of their fabrication and inspection activities with the NRC.

General Recommendation Number[1]	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR13	The construction methods proposed for use are assumed to be available and are heavily dependent on new construction technologies requiring specialized equipment. It is not clear that these assumptions are valid or that vendors have identified or planned how to meet the prerequisites (e.g. training, transportation, equipment set-up) to enable use of these technologies.	The vendors should review the availability and transportation requirements for the specialized equipment required to achieve construction schedules. Additionally, the requirements for training on these tools and techniques should be assessed. Preparations for use of new technologies key to shortened construction schedules should be planned into project schedules as part of pre-construction work.	DOE / Industry Strategic Plan SOW for Objective 1-3 includes development of construction technologies to shorten construction schedules for new nuclear plants. MPR is also preparing report MPR-2610 "Application of Advanced Construction Methods to New Nuclear Power Plants" for DOE that identifies and provides recommendations for enabling the use of advanced construction technologies.	It is expected that vendors will work with constructors to establish timelines and plans for fulfilling the prerequisites to enable the construction techniques that are key to the shortened construction schedules.
GR14	The schedules provided did not have installation rates for the various commodities clearly stated. Thus, the feasibility of achieving these rates could not be evaluated.	Installation rates assumed in the schedules should be evaluated by the vendors and constructors to ensure that they are feasible.	None.	It is expected that vendors and constructors will prepare resource-loaded schedules with clear references for commodity installation rates to enable potential owners to perform more thorough due diligence in assessing whether construction schedules are achievable.

General Recommendation Number[1]	Finding	General Recommendation	Action in Progress or Planned	Additional Action
GR15	Vendors do not yet have resource-loaded schedules and thus their assumptions about labor productivity and shifts/working hours could not be evaluated.	The vendor schedules should be resource-loaded to allow for further examination of schedule feasibility.	None.	See Additional Action for GR14 above.

Note 1: Recommendations specific to each reactor design are in Section 4 of this report.

4 Plant-Specific Conclusions & Recommendations

The construction schedule evaluation identified a number of strengths and weaknesses in the schedules provided by each of the four nuclear vendors. These conclusions are discussed in the following sections along with specific recommendations for additional work that can mitigate the risks associated with the schedules. While all recommendations require action by the vendors, other parties, such as the DOE, regulators, or potential owners, may also be able to contribute to their resolution. Where appropriate, these contributing actions are noted in parentheses. The numbers (e.g., GR1) within the notes refer to applicable general recommendations summarized in Table 3-1.

4.1 Toshiba ABWR

4.1.1 Project and Schedule Development Status

Design Certification was received for the ABWR from the NRC in May 1997. In addition, two ABWR plants (K-6 and K-7) have already been built in Japan, and four additional ABWR plants are currently under construction.

Based on this experience, Toshiba has a strong basis for their 55-month NOAK construction schedule (from start of site preparation to commercial operation). Specifically, Toshiba has based the schedule largely on the actual construction of K-6 and has claimed that the K-6 schedule is repeatable for future ABWRs.

4.1.2 Schedule Conclusions and Recommendations

The schedule information provided by Toshiba presents only a summary-level overview for future ABWR units in Asia (not in the U.S.), without detailed explanation. Therefore, some of the detailed review described in Section 1.4 could not be performed. The evaluation, which is documented in Appendix A, focuses mainly on identifying the issues that will affect future deployment in the U.S., as opposed to Asia. The conclusions resulting from this evaluation are listed below. Where appropriate, recommendations for mitigating the schedule risk are provided.

1. Actual construction of K-7 and Hamaoka Unit 5 (H-5) had noticeable deviations from the K-6 and the proposed schedule. The deviations occurred primarily during site preparation, testing, and commissioning. In general, the durations for building and system construction were similar for all three units. This lends confidence that the construction durations are repeatable, and thus are also achievable for future U.S. deployment. Site preparation, testing, and commissioning activities in the U.S., however, may be significantly different. These activities should be developed further for U.S.

deployment, and the schedule revised accordingly. *(General recommendations GR2 and GR12 apply.)*

2. Engineering for the ABWR is largely complete. Engineering for the reactor design was completed for the DC that was issued in 1997 and for previous ABWR construction projects. Site-specific engineering activities will be required for new construction. These activities have not been explicitly called out in the provided schedule, but the supporting text states that these activities will require two years prior to first structural concrete. Toshiba's predicted durations for COL and ESP licensing reviews are long enough to perform the required site-specific engineering in parallel. It is recommended that the schedule be revised to assume a specific U.S. site and that required site-specific engineering activities be fully incorporated into the schedule. *(Potential owners and constructors could assist in defining the U.S. site and conducting more extensive studies.)*

3. Details of the construction engineering will need to be modified for U.S. deployment due to differences in infrastructure and regulations. In addition, Toshiba assumes increased modularization over past projects. Modules employed in past projects are well-developed, but the additional modules will be FOAK. These design activities are expected to take one year (Reference 2.5), but it is uncertain when this engineering is planned or whether it may affect the procurement of long-lead items. Therefore, a study should be conducted to identify and quantify the required additional design work and durations. Once the changes have been better identified, the impact on the remaining schedule can be evaluated. *(The vendor, A/E firms and constructors should collaborate for this study.)*

4. Vendors used to supply some major equipment in Asia, such as the reactor pressure vessel (RPV), will likely also be used for U.S. deployment. However, new vendors will be sought for other equipment and bulk materials in order to reduce transportation costs. It is not clear whether the activities required to establish new vendors were considered within the provided procurement durations. Therefore, the procurement durations should be reviewed to ensure that they can support the activities required to establish new vendors. *(General recommendations GR11, GR12 apply; potential owners, constructors and the vendor should determine what relationships already exist and investigate the ability of those relationships to meet project needs.)*

5. The planned "just-in-time" procurement system requires detailed planning and lead-time estimates. Factors such as relative vendor site locations and transportation durations are likely to require adjustment for U.S. deployment. Past ABWR units have been located near a coastline, allowing the majority of modules to be shipped via barge. Furthermore, the construction schedule assumes a site with barge access for large module procurement, and special provisions for rail/road transport have not been investigated. Transportation of large modules, specifically the RPV, will be a challenge for land-locked U.S. sites because the large modules exceed the maximum allowable weight for rail and road shipments. In order to address this, the transportation methods and durations in the current schedule should be further evaluated to ensure that they are achievable in the U.S. Other vendors are not planning on having barge access to the plant site and have made provisions to limit module size and weight. Toshiba should consider the effects of this

possible constraint on their schedule. *(General recommendations GR11, GR12, and GR13 apply, and potential owners should assess the feasibility of currently projected procurement durations.)*

6. Although construction activities were not well detailed in the provided schedule, ABWR construction activities are expected to be very well-developed from past projects. The logic and durations associated with these activities are not expected to change significantly for U.S. deployment.

7. Although all four reactor schedules include assumptions regarding labor conditions, the assumptions in the other vendor schedules are based on U.S. labor conditions. The ABWR schedule was developed based on the labor conditions in Japan during the construction of K-6. These conditions may vary significantly for future U.S. deployment. Furthermore, the ABWR schedule is considered the most likely of the four evaluated vendor schedules to have deviating labor conditions. The potential effects of these differences should be identified, and the schedule adjusted accordingly. *(The vendor, constructors, and potential owners should collaborate for the study of these differences.)*

8. The period between fuel load and commercial operation of the ABWR is one to two months shorter than that achieved during commissioning of K-6 and K-7. This reduction is based on a study of learning curve effects, which can be expected in the start-up testing of future ABWR units. This 7-month test period will require a work schedule based on working 14 hours for 6 days per week and includes approximately 2 weeks of contingency time. If the work schedule can be supported by available labor conditions, this duration is considered achievable. However, the expected U.S. labor conditions should be studied to determine if available labor will be able to support the existing work schedule. If labor availability will not be able to support the schedule, the start-up test durations should be adjusted as necessary. *(General recommendation GR7 applies.)*

9. Training activities were addressed briefly in the supporting text. It is assumed that training materials have been well-developed in past ABWR projects and will provide a starting basis for future deployment. Some effort will be required for translating existing training materials into English and other activities for adapting existing procedures to U.S. requirements. It is recommended that a study of U.S. training regulations and practices be conducted to determine if the personnel training conducted in Asia is consistent with U.S. requirements. Additionally, all required training activities, including necessary developmental activities, should be incorporated into the schedule. *(General recommendation GR9 applies.)*

4.2 GENERAL ELECTRIC ESBWR

4.2.1 Project and Schedule Development Status

The GE ESBWR evolved from the BWR, ABWR, and SBWR designs into a plant that GE believes is simpler, more flexible, and more economic than any other design currently available.

The status of the ESBWR project reflects this evolutionary path as the project is currently a hybridization of the ESBWR engineering design, which is nearly complete for DC application, and the fully fleshed-out construction, modularization plans, and schedule from their ABWR. Independent construction, modularization plans, and schedules have not yet been developed for the ESBWR. However, GE is working out these details and plans to submit the ESBWR DC application by mid-2005. GE is currently in the pre-application phase of design reviews with the NRC.

In the submitted materials, GE provided only a summary schedule for a FOAK plant which combines all elements of the ABWR construction plan on a high level. The summary schedule provides the groundwork for understanding the steps from plans to plant, but additional detail is needed to understand the thought processes behind the construction of the plant.

4.2.2 Schedule Conclusions and Recommendations

Detailed reviews of the ABWR schedule have been conducted and are applied to the design of the ESBWR, where possible. These reviews are documented in Appendix B. It appears that the 60-month schedule (from CED to unit completion) proposed by GE is achievable. The conclusions resulting from these reviews are listed below. Where appropriate, recommendations for mitigating the schedule risk are provided.

1. One primary assumption is that most engineering work will be completed prior to the beginning of any physical work. However, the detailed design of certain buildings (i.e., the annex and administration buildings) will only be performed once the owner has committed to the site and the project. This way the buildings will best suit the particular needs of the owning utility. Delaying the design of these buildings prevents the addition of unnecessary or redundant engineering work, but will add additional site-specific engineering time to the final schedule. *(General recommendations GR1, GR4, GR8 apply.)*

2. GE discusses relationships with component vendors in good detail within their construction plan narrative. However, the effects of the identified issues are not apparent within the schedule. Additional levels of schedule detail should be provided to understand what kind of time frame is considered necessary to establish vendor relationships. *(General recommendations GR11 and GR12 apply.)*

3. GE discusses transportation concerns, such as on-site traffic and delivery areas, in good detail within the construction plan narrative to address the flow of physical work on site. However, these concerns are not apparent within the schedule. Additional levels of detail should be provided to understand the time allowed for on-site work flow activities. *(General recommendations GR14 and GR15 apply.)*

4. Little detail is provided either for shop testing and qualification or for systems checks and tests prior to turnover. Durations that could be affected by these details should be evaluated to ensure that sufficient time is available. More detail on what tests will be performed is required before this evaluation may be performed. *(General recommendations GR 11 and GR12 apply.)*

5. GE recognizes that lessons learned on the first plant will be critical to improving durations and construction practices on NOAK plants. However, GE states that reductions and plans for NOAK plants have not been formulated, and believes this topic may be better addressed after the experience of constructing a FOAK plant.

6. Assessments of ESBWR constructability should be performed after the buildings and systems have been further defined. The quantity and level of detail of information provided for the ABWR provides confidence that GE understands what will be required for the ESBWR, however, final recommendations on the readiness of their schedule cannot be provided until the design is more fully complete.

7. Excellent assessments of the project management and human resources needed to support the on-site work were provided. This initial infrastructure provides assurances that strong management strategies will underlie the entire construction process. GE plans to improve upon previously achieved durations and schedules through improved management techniques as well as advanced technology.

8. GE performed a risk analysis on their ABWR schedule and provided the results. The analysis targets assumptions which pose the highest potential impact to the schedule to allow the management team to focus on ways to minimize the risk of negative events. This analysis, teamed with independent outside reviews of the construction plan, lends confidence to the achievability of their construction schedule.

9. Due to GE's recent experience with construction of the ABWR at Lungmen, Taiwan they were able to provide schedule and quantity information for the construction of a training simulator. Additional work is required before the simulator design and construction plan are ready to be constructed and implemented in the U.S.; however, the current level of detail is considered to be sufficient for this stage of the process.

4.3 AECL ACR-700

4.3.1 Project and Schedule Development Status

The ACR-700 is designed to be an evolutionary enhancement of previous CANDU reactor designs, specifically the CANDU 6. The changes in the plant are intended to improve economics, safety, and performance. An emphasis has also been placed on achieving the shortest practical construction schedule. To this end, AECL has simplified the design of the plant and planned extensive use of modularization, which will allow fabrication activities to proceed in parallel with site preparation.

AECL is currently in the DC pre-application review phase with the NRC. Based on NRC's latest update on the status of new reactor licensing activities (Reference 4.5), AECL expects to submit the DC application to the NRC in the fall of 2004. Per the licensing schedule provided by AECL (Appendix C of Reference 4.1), they expect the DC to be issued in April 2008.

AECL developed a series of logic-driven schedules that integrate all project phases leading to the commercial operation of the first of a two-unit ACR-700 station. AECL states that the second ACR-700 unit could be completed 12 months after the first. However, a construction schedule was not provided for the second unit.

Although an ACR-700 unit has never been constructed, AECL has recent CANDU 6 construction experience with the Qinshan plant in China. This plant was completed in the summer of 2003. That experience forms much of the basis for the ACR-700 schedules.

4.3.2 Schedule Conclusions and Recommendations

It appears that the schedule proposed by AECL is achievable. However, reviews of the ACR-700 schedules, documented in Appendix C, identify issues that could impact the planned construction duration of 60 months (from start of site preparation to commercial operation). The conclusions resulting from this evaluation are listed below. Where appropriate, recommendations for mitigating the schedule risk are provided.

1. AECL assumes the following related to licensing issues (see Figure C-1 in Appendix C):

    - The issuance of an ESP, which is a prerequisite to site preparation activities, coincides with the CED.
    - The DC is issued three months after CED.
    - The combined COL, which is a prerequisite to first concrete, is issued 12 months after CED.

    This proposed licensing schedule is particularly aggressive considering the uncertainties discussed in Section 2.1.4. AECL should reexamine the potential risks associated with this schedule. *(General recommendation GR2 applies.)*

2. AECL assumes that engineering and some procurement activities (i.e., bid evaluations and contract negotiations) will commence prior to CED. Because of the potential uncertainty and complexity of the commercial agreements associated with a FOAK nuclear construction project, it is unclear how much effort an owner would be willing to invest prior to CED. As this issue would be considered on a project-by-project basis, schedule impact is difficult to assess.

    In the NOAK schedule, AECL assumes that site preparation will precede CED (as opposed to the FOAK schedule where site preparation succeeded CED). It is also likely that the manufacturing of some critical long-lead equipment will be required prior to CED. Although commercial uncertainty is reduced with an NOAK project, there is still risk associated with this issue.

3. To meet the proposed schedule, some major equipment must be manufactured, assembled, and shipped in less time than has been achieved on past projects (e.g., Qinshan). AECL is currently evaluating manufacturing and procurement practices to determine if the durations required are achievable. High confidence is necessary to

ensure subsequent module fabrication and construction activities will not be impacted. Therefore, additional effort in this area may mitigate risk. *(General recommendations GR8, GR11, GR12, and GR13 apply.)*

4. Module fabrication durations are of particular importance because several module fabrication activities are on the critical or near-critical path. AECL assumes that module fabrication durations will range from four to six months depending on complexity. Although this assumption appears to be reasonable, additional module design effort and vendor input are recommended to increase the confidence in these durations. *(General recommendation GR13 applies.)*

   Note that AECL does not currently plan to issue purchase orders for any major equipment or modules prior to CED. However, the potential for module fabrication to impact the critical path could be reduced by ordering some of the critical equipment before CED. (Note that it is not certain that this option would be available as discussed in Conclusion 2 above.)

5. AECL states that the Calandria and Shield Tank Assembly (CSTA) will be manufactured in Canada at a location with access to navigable water. AECL plans to transport the CSTA via water and, therefore, assumes that the construction site also has access to navigable water. It is unclear whether this is a technical requirement for the CSTA or if it was assumed to shorten the transportation duration. The feasibility and duration of alternative CSTA transportation options should be evaluated. *(General recommendation GR13 applies.)*

6. AECL plans to construct 105 modules in a 24-month period. As previously discussed (Conclusion 4), it is assumed that each module will take four to six months to complete. Therefore, it appears that an average of 16-25 modules will need to be fabricated at the same time throughout the 24-month period to support this schedule. This level of parallel activity will be challenging. AECL has recognized this issue and plans to manage each module as a “mini-project” to help to ensure that each module is adequately monitored and managed.

7. Activities for testing of equipment and modules before they are transported from the fabrication shop are not included in the schedule. While, these are alluded to in documentation provided, it is not clear whether they were considered when fabrication durations were assigned. Therefore, fabrication durations should be reviewed to ensure that sufficient time is included for shop-testing activities. *(General recommendation GR3 applies.)*

8. The schedule does not include detail on tasks that must be accomplished during site preparation (e.g., soil preparation, road construction, etc.). These are alluded to in the documentation; however, it is not clear whether they were considered when site preparation durations were assigned. Additionally, the proposed site preparation duration is four months shorter than was achieved at Qinshan. Therefore, the site preparation duration should be evaluated further. *(Potential owners and constructors should assist in defining the U.S. site and conducting more extensive studies.)*

9. The ACR-700 construction phase schedule is approximately seven months shorter than was achieved at Qinshan. This time savings is primarily attributed to the increased use of modularization and prefabrication. However, because large-scale use of modularization has never been used during the construction of a nuclear plant in the U.S., this assumption is an area of risk.

10. The duration assigned for the final testing and startup of the plant following fuel load is two months longer than was achieved at Qinshan. Although AECL does not provide a rationale, this extra time may have been included as float in the start-up schedule to address emergent issues.

11. Several potential areas of risk associated with simulator development have been identified:
    - Activities associated with the engineering design of the simulator are not included in the schedule. It is recommended that this scope be defined so that its impact on the schedule can be evaluated.
    - AECL assumes the duration for manufacturing the simulator is 18 months, but does not provide a justification for this value. It is recommended that this assumption be further evaluated to ensure that it is achievable.
    - The schedule shows the simulator being completed and shipped before most of the equipment in the plant, including the Control Centre and other instrumentation and control (I&C) equipment, is completed and tested. It is recommended that options be evaluated to make test data available for critical I&C equipment before the simulator is shipped to the site.
    - AECL is planning to conduct simulator software verification on-site after the simulator has been installed and commissioned. Therefore, it is important that the vendor establish a high level of confidence that minimal errors will be identified during the software verification process. This level of confidence could be achieved by investing significant effort into in-process software verification activities.

    These issues are of significant importance because the simulator development and operator training activities have been identified as a near critical path. *(General recommendations GR9 and GR10 apply)*

4.4 WESTINGHOUSE AP1000

4.4.1 Project and Schedule Development Status

The AP1000 is a PWR with a passive safety design. The use of passive safety systems has significantly reduced the number of safety-related construction and commissioning activities. The AP1000 is a higher power version of the AP600, which was designed by an international team headed by Westinghouse and which received DC in December 1999.

The AP1000 and the AP600 have been designed to meet the standards set by the utilities, Electric Power Research Institute (EPRI), and DOE as described in the ALWR URD. Approximately 450 million dollars have been spent to develop the AP1000/AP600 design, cost, and schedule. Westinghouse indicates that approximately 400 million dollars of effort remain to achieve 100% completion of the AP1000 design. The AP1000 is currently being reviewed by the NRC, with DC expected in December 2005.

Westinghouse prepared and refined a 5700 activity, Level 3 schedule for an NOAK, single-unit, AP1000 plant. Although an AP1000 plant has never been constructed, Westinghouse has developed a high level of confidence in their schedule through the extensive reviews and analysis.

4.4.2 Schedule Conclusions and Recommendations

Detailed reviews of the AP1000 schedules have been conducted and are documented in Appendix D. Based on these reviews, it appears that the NOAK 60-month schedule (from start of site preparation to commercial operation) proposed by Westinghouse is achievable. The conclusions resulting from this evaluation are listed below. Where appropriate, recommendations for mitigating the schedule risk are provided.

1. While Westinghouse has stated that testing of equipment and modules will be required in the fabrication shops, these activities are not identified separately within the detailed schedule. Therefore, testing activities should be added to the schedule to ensure that the full scope has been identified and that fabrication durations are sufficient to allow all testing. *(General recommendation GR3 applies.)*

2. AP1000 procurements are assumed to be made sufficiently early to force them off the critical path by at least 30 days. This is reasonable for initial schedule development, but procurements for long lead items will be driven by the owner willingness to accept risk early in the project. Therefore, it is recommended that Westinghouse review the procurement schedule assuming that procurements are limited by some likely milestones, such as COL issue, to determine the potential impacts to the critical path. *(General recommendations GR2 and GR11 apply.)*

3. Westinghouse has proposed to accelerate the overall schedule by starting site preparation activities in parallel with COL activities. A LWA would be obtained from the NRC partway through the COL process to allow this work to take place.

   Westinghouse personnel are aware of the potential commercial risks associated with this arrangement. If COL is to be obtained prior to the start of procurements and site preparation, this would push the construction of a potential plant further into the future, but should not lengthen the overall on-site construction period.

4. The NOAK licensing schedule for AP1000 is accelerated by the use of “pre-approved” COL packages developed for non-site-specific application portions. This innovative approach may be able to speed the COL application preparation and review time periods.

However, caution should be used when evaluating the NOAK schedule to estimate the FOAK plant. Additional time will be required for licensing activities for the FOAK plant. *(General recommendations GR2 and GR3 apply.)*

5. The detailed AP1000 schedule has been developed for an NOAK plant. Westinghouse states a 60-month construction schedule (18 months for site preparation, 36 months for construction, and 6 months for final commissioning).

   For a FOAK plant, Westinghouse states a 60-month construction schedule, but adds an additional year of planning on the front end. This logic adds risk to the FOAK schedule compared with the NOAK. While the 60-month schedule appears to be feasible in either case, the additional risk in the FOAK schedule may not be acceptable to potential owners. We recommend that Westinghouse update their risk analysis to review the AP1000 schedule for overall expected risk and to highlight the areas of highest risk for FOAK and NOAK assumptions. Additionally, the risk analysis should include new information about utility preferences for early procurements and licensing risk. *(General recommendation GR2 applies.)*

6. The AP1000 engineering schedule is limited to site-specific activities. This is an appropriate assumption for the NOAK plant. However, because the FOAK engineering activities are expected to be substantial, Westinghouse should also identify all engineering activities to support FOAK construction. *(General recommendations GR1 and GR4 apply.)*

7. Westinghouse provided documentation of a risk analysis performed on their AP600 schedule. The analysis allowed the management team to focus on ways to minimize risk impacts. This analysis, combined with the multiple independent outside reviews performed on the construction plan, adds confidence to the achievability of the construction schedule.

8. The licensing schedule includes post-COL activities that appear to be preparations for NRC reviews or the conduct of NRC reviews of critical technical and operational programs, ITAAC, and procedures. These activities are defined at a relatively high level and do not appear to be fully complete. However, they indicate that Westinghouse has examined required inspection and licensing activities. Westinghouse should continue to develop activities for licensing, inspection, and ITAAC activities and make appropriate adjustments to the schedule. *(General recommendation GR3 applies.)*

9. High level man-hour estimates have been developed for the AP600 schedule, however, the Level 3 schedule has not been resource loaded otherwise (with the exception of Nuclear Island concrete). Additional resources should be loaded into the schedule based on detailed estimates of labor and equipment levels. *(General recommendations GR7 and GR15 apply.)*

10. Westinghouse should further define and develop the scope of work required for the simulator design, construction, and operation. *(General recommendations GR9 and GR10 apply.)*

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A Toshiba ABWR

1. Background

The Toshiba Advanced Boiling Water Reactor (ABWR) is an evolutionary design that improves upon 40 years of cumulative experience in the design, development, and operation of current Boiling Water Reactors (BWRs). Development of the ABWR began in 1978 in an international joint effort between five BWR vendors, of whom GE and Toshiba were the primary U.S. and Japanese developers, respectively.

The ABWR received Design Certification (DC) from the U.S. Nuclear Regulatory Commission (NRC) in 1997. Also, it is the only reactor in this study that has already been constructed, with two units operating in Japan and four more units under construction in Japan and Taiwan. Toshiba, with the aid of GE, designed and constructed the Kashiwazaki-Kariwa Units 6 and 7 (K-6 and K-7, respectively) for Tokyo Electric Power Company (TEPCO). Construction of the two units began in 1991 and 1992. K-6 began commercial operation in late 1996, and K-7 began commercial operation shortly after in 1997.

Toshiba's current ABWR design deviates slightly from the GE/Toshiba design, which received certification in 1997. An explicit listing of the differences was not provided. From a review of the provided documentation, only two differences were identified. The 1997 GE/Toshiba design was for a one-unit ABWR, while the current Toshiba design is for a two-unit ABWR (See Figure A-1). Also, the current Toshiba design incorporates advanced seal-less fine-motion control rod drives (FMCRDs) for greater reliability, an evolutionary improvement over the FMCRDs of the 1997 design. It is Toshiba's position that these types of changes do not invalidate the 1997 DC and can be resolved during the COL review. However, any departure from the 1997 DC must be approved by the NRC. Since the licensing process is not fully developed, it is not obvious at the moment that all differences from the certified design can or will be reviewed at the COL stage. The NRC may require that all changes in the Toshiba design be incorporated into the generic certified design documents prior to the COL application, effectively requiring design recertification for the Toshiba ABWR. At present, the extent of the required effort for recertification is unknown. Further changes from the 1997 certified design should be minimized to prevent additional growth in cost and scheduling resulting from recertification.

Initially, a construction schedule for the ABWR was developed by GE in 1997 to support design certification. The current schedule provided by Toshiba is based on the actual construction schedule experienced with K-6, which realized shorter construction times than originally proposed by GE. This schedule has been shortened somewhat (by one month) to incorporate learning curve effects expected for future NOAK ABWR units constructed in Asia. In Reference 2.5, Toshiba also provided milestone dates achieved during construction of K-7 and Hamaoka

Unit 5 (H-5). The construction durations for K-7 and H-5 had noticeable deviations from those of K-6. Further investigation revealed that these deviations occurred during site preparation and during system testing and commissioning. The durations for construction activities were very similar, lending confidence to the repeatability of the proposed schedule.

The schedule provided by Toshiba only covered high-level construction activities. It was assumed that all necessary details have been well-developed and proven in past ABWR construction projects, even if the activities were not included in the provided documentation. Toshiba is currently performing a construction schedule evaluation study in order to adapt their ABWR schedule for U.S. deployment. Since this study is still in the early stages, the results were not available for this report. The current schedule provided by Toshiba is for an NOAK ABWR unit constructed in Asia and does not include provisions for additional activities or issues necessary for U.S. construction. Therefore, the main focus of this evaluation has been to identify aspects of the construction schedule which will require revision or additional development for future ABWR deployment in the U.S., rather than in Asia.

1.1. Plot Plan

To orient the reader to the layout of the ABWR, a plot plan from Reference 2.1 is provided in Figure A-1.

1.2. Systems and Equipment

The major buildings and systems of the Toshiba ABWR are included below:

<u>Reactor Building (See Figure A-2)</u>

- Primary Circuit
  - Reactor Pressure Vessel (RPV)
  - Main Steam Lines (MSLs)
  - Feedwater Lines (FWLs)
  - Main Steam Line Flow Limiter
  - Main Steam Isolation Valves (MSIVs)
  - Nuclear Pressure Relief System
  - Automatic Depressurization System
- Reactor Core and Fuel
  - Reactor Internal Pumps (RIPs)
  - Control Rod Drive System
    - Seal-less Fine Motion Control Rod Drive (FMCRD)
    - Hydraulic Control Unit (HCU)
    - Control Rod Drive Hydraulic Subsystem (CRDH)
- Fuel Handling and Transfer Systems
- Safety Systems
  - Emergency Core Cooling System (ECCS)
  - Emergency Diesel Generator (EDG)
  - Standby Liquid Control System (SLC)
- Reactor Auxiliary Systems
  - Reactor Building Cooling Water System (RBCW)
  - Reactor Water Cleanup System (RWCU)
  - Fuel Pool Cooling and Cleanup (FPCU)
  - Suppression Pool Cleanup System (SPCU)

<u>Turbine Building</u>

- Turbine Bypass System (TBP)
- Condenser Circulating Water System (CCW)
- Main Condenser Evacuation System (MCES)
- Steam Jet Air Ejectors (SJAEs)

- Condensate and Feedwater Systems
- Turbine Building Cooling Water System (TBCW)
- Turbine Building Service Water System (TBSW)
- Service Air System (SAIR)

Control Building

- Main Control Room Panels (MCRPs)
- Safety System Logic and Control (SSLC)
- Reactor Protection System (RPS)
- Essential Multiplexing System (EMS)
- Remote Shutdown System (RSD)
- Standby Liquid Control System (SLC)
- Feedwater Control System (FWC)
- Neutron Monitoring System (NMS)
  - Startup Range Neutron Monitoring Subsystem (SRNM)
  - Power Range Neutron Monitoring Subsystem (PRNM)
  - Automatic Traversing In-Core Probe Subsystem (ATIP)
  - Multi-channel Rod Block Monitor Subsystem (MRBM)

2. SCHEDULE ASSUMPTIONS

2.1. Fundamental Project Assumptions

1. The ABWR schedule is for an NOAK plant located in Japan. Two ABWR units have already been constructed, reducing the learning curve and resulting in an already complete detailed reactor design.
2. Toshiba's future ABWR construction schedule is heavily based on experience gained in constructing K-6 and K-7. Toshiba assumes the actual K-6 construction schedule as the baseline schedule for future ABWR plants.
3. Toshiba assumes that evolutionary improvements in the construction process, such as increased modularization, will result in shortening the construction time by one month, compared to the K-6 baseline.
4. The 1st unit deployed in the U.S. will require additional qualification tests, including a Structural Integrated Test (SIT) to measure strains in the containment structure. It is assumed that this will require an additional few weeks, but will not impact the critical path.
5. Required vendor relationships have already been established. Toshiba has established a network of international vendors in constructing the K-6 and K-7 reactors. Additional vendors may be sought depending on the location of future plants.
6. Adequate funds are available to prevent financial delays. Procurement of materials and components will not be limited by restricted cash flow.
7. The schedule is based on a work schedule of eight-hour shifts with six days off (four Sundays, two Saturdays) per four weeks. This work schedule results in an average of 44 hours per week. Critical and sub-critical path activities are performed on an overtime basis as needed. This overtime work is performed either with extended shifts (nine to eleven hours) or on days off (weekends and holidays), depending on the scale of the activity.
8. It is assumed that sufficient craft and labor is available for both on-site and off-site work.

9. The schedule does not provide contingency time for *force majeure* events such as extensive labor strikes or bankruptcy of major subcontractors/suppliers.
10. It is assumed that future projects will utilize project management tools similar to those employed during the construction of K-6. These include, for example, the use of electronic databases for drawings and documents, extensive 3D CAD models, field media boards for displaying work instructions or procedures, video conferencing, and three-week/three-month rolling schedules.

2.2. Licensing and Permitting Assumptions

11. The ABWR design is 100% design certified, and was awarded a Design Certification by the NRC in 1997. It is assumed that the current Toshiba ABWR design does not require additional design engineering or review by the NRC. Specifically, the improvements since 1997 are limited to evolutionary technology improvements (e.g., elimination of seals in the FMCRDs), which will be resolved during the COL review period.
12. The ABWR schedule assumes a COL and/or ESP will be required, and allows time for these activities. It is assumed that ESP review will require 33 months, and COL review will require 27 months (with and without a separate ESP). These durations are taken from the NRC document SECY-01-188, "Future Licensing and Inspection readiness Assessment."
13. Although first structural concrete requires COL approval, site preparation commences with the issue of a Limited Work Authorization (LWA) during the COL review period.
14. It is assumed that all design activities have been completed and that all regulatory issues have been resolved by the time the COL is approved. That is, no design changes will be required during the construction stage.
15. The schedule assumes that regulatory inspections have been scheduled before the start of construction and do not affect the overall schedule.

2.3. Site-Specific Assumptions

16. The schedule assumes a suitable location that will satisfy environmental, seismic, soil, and hydrology requirements.
17. No specific location is assumed. In Reference 2.5, Toshiba provided an assumed site location within the southeastern U.S. Upon further investigation, this site assumption was made for the PDRI/PPMOF[14] evaluation and was not used in developing the construction schedule. The schedule is based on previous construction experience for the K-6 reactor located in Kashiwazaki, Japan. Therefore, the schedule assumes a site location similar to Kashiwazaki, Japan.

[14] The Project Definition Rating Index (PDRI) is a tool developed by the Construction Industry Institute (CII) to evaluate each of the elements critical to a project to gauge the potential success of the project. The CII developed a similar tool for Prefabrication, Preassembly, Modularization and Off-site Fabrication (PPMOF). The results of the PDRI/PPMOF evaluation are not addressed in this report, but are included in the Dominion Study.

18. The site is assumed to be located near the coast. This is desirable since it allows for barge transportation of large modules without requiring special permitting or other measures for rail/road transportation.
19. An all-weather enclosure may be constructed over the site, allowing construction work to continue year round. The decision to use an all-weather enclosure will depend on the severity of the weather conditions at the site.
20. It is assumed that the site can be cleared and graded within three months following being granted LWA.
21. It is assumed that seismic activity at the site is within the safety envelope of the ABWR. The ABWR reactor building and containment have been qualified for a safe shutdown earthquake of 0.3g.
22. The ABWR assumes no source of external cooling water is available at the site, and includes provisions for cooling towers.

2.4. Construction Assumptions

23. The ABWR uses open-top construction to reduce carry-in and set-up times for bulk materials and equipment. It is assumed that 95% of equipment, 70% of large-bore piping, and 35% of cable-trays will be loaded via the open-top construction method. Toshiba has already developed the necessary cranes and other construction equipment during construction of K-6 and K-7.
24. The ABWR relies heavily on modularization to reduce construction times and on-site labor. It is assumed that the amount of modularization in future ABWR construction will increase compared to K-6 and will result in shorter construction time.
25. As mentioned above, the ABWR may employ an all-weather enclosure during construction. This prevents weather delays and also contains internal cranes and other equipment to increase productivity.
26. It is assumed that the majority of welding and rebar work will be accomplished using automated machines for increased quality and productivity.

2.5. Engineering and Procurement Assumptions

27. All engineering for the ABWR has been completed for the K-6/K-7 plants. It is assumed that all specifications and bid documents have already been developed and will be available for future ABWR plants.
28. Equipment and bulk commodities will be delivered on a "just-in-time" basis in order to minimize on-site storage requirements. All procurement activities are assumed to have sufficient lead-time and funds to prevent delays.
29. As mentioned above, Toshiba has already established relationships with international vendors. However, it is assumed that Toshiba will seek out new vendors, if necessary, to reduce delivery times and to remain on schedule.
30. All shipping, handling, and preventative procedures have already been established during construction of K-6 and K-7.

31. The RPV, RCCV liner, and other long-lead items will be ordered during the licensing phase, prior to commencement of on-site work.
32. The site is assumed close enough to the coast that the majority of equipment will be transported by barge. Barge-accessible sites are assumed for the procurement of large modules, since barge access is desirable in order to avoid special permitting or other measures required for rail/road transportation.

3. DETAILED SCHEDULE EVALUATION

A detailed evaluation was performed using the approach described in Section 1.4.2 on the following phases of the ABWR schedule: Engineering, Procurement, Construction, Start-up and Commissioning, Training, and Licensing Inspections and ITAAC. The results of the detailed evaluation are provided in Tables A-1 through A-6 and summarized below.

3.1. Engineering

Table A-1 provides the detailed evaluation results for the ABWR engineering activities. The information provided by Toshiba is generally considered to be reasonable. The GE ABWR design received Design Certification from the NRC in 1997. In addition, Toshiba has already constructed two ABWR units at the Kashiwazaki-Kariwa nuclear power station (K-6 and K-7) for the TEPCO. A number of additional ABWR units are also under construction in Japan and Taiwan. The documentation provided by Toshiba did not include detailed engineering activities. However, most of the module and overall construction engineering is assumed to be complete, considering past ABWR certification and construction.

Additional module design activities will require approximately one year prior to the start of construction (Reference 2.5), although further details concerning the scope of the activities and exact start date were not provided. These activities are expected to be limited mainly to new modules resulting from the increased modularization for future ABWR projects, compared to K-6. The degree to which these additional modules have already been developed for units currently under construction is not evident. Specifically since K-6, the modules used in the RCCV have been redesigned. Since these modules are long-lead items, engineering development for these modules must be completed very early.

Site-specific engineering activities will still be required for future U.S. deployment of the ABWR. These activities were not discussed in detail, but they will require approximately two years in order to complete (Reference 2.5). Toshiba provides 27 months for COL review, and 33 months for ESP review (if a separate ESP is desired). These durations are considered long enough to perform site-engineering in parallel. Furthermore, it is possible to accelerate engineering activities, to a degree, simply by applying more man-hours over a given time period. Therefore, site-specific engineering activities can be reasonably performed in parallel with pre-construction licensing activities without delaying other activities.

From TEPCO progress reports (Reference 2.3), simulator development was completed for K-6 and K-7 prior to pre-operational testing. Operator simulator training was performed through the

BWR Operator Training Center Corporation located in Japan. Therefore, simulator development tasks are assumed to be well-developed from past efforts, but still require some effort for future ABWR deployment. An overview of simulator activities was provided by Toshiba (Reference 2.5). Design, manufacture, and delivery of the simulator will require 78 weeks. This period begins somewhat arbitrarily 10 months after first structural concrete, without a requisite predecessor. Therefore, simulator design can be moved forward in the schedule if more time is required. These durations and logic are considered reasonable given the simulator experience gained during past ABWR projects.

3.2. Procurement

Table A-2 provides the detailed evaluation results for the ABWR procurement activities. The schedule provided by Toshiba does not include detailed activities for the procurement of materials, modules, and components. Toshiba provided a list of available vendors, which were established during construction of K-6 and K-7. Also, it is assumed that all procurement procedures have already been established during previous construction, since fabrication-level drawings have already been completed (Reference 2.5). Additional vendors may be necessary for U.S. deployment in order to reduce transportation time and costs, especially for bulk materials. If so, the schedule should be updated to allow sufficient time for bid evaluation and other activities required to establish new vendor relationships.

The information provided by Toshiba did not include explicit transportation durations. These durations depend on the site and vendor location, both of which are uncertain at this point. Moreover, the durations will not be the same as those for K-6 and K-7. Procurement will typically follow a "just-in-time" methodology, which requires detailed and well-planned scheduling to prevent delays. Therefore, these durations should be established and incorporated into the schedule for future deployment in order to confirm that lack of material or components will not delay construction.

Procurement of general modules is also not detailed in the information provided by Toshiba. It is assumed that all general module fabrication and qualification procedures have already been established during past construction and do not require significant changes for future U.S. deployment. It is uncertain whether module fabrication must begin prior to COL approval or whether multiple fabrication shops are required to prevent delays. These details should be incorporated into the schedule. However, it is expected that sufficient provisions can be taken to prevent these details from affecting the overall construction schedule.

For long-lead items, the schedule provides high-level procurement activities for the RPV and RCCV. Although not explicitly labeled as such, procurement of these components is expected to be critical path and should therefore be addressed in greater detail. Fabrication durations are not expected to change significantly from those in construction of past units. The schedule also includes a delivery period for the RPV, which will change depending on site and vendor location. In addition, site installation of the RPV begins approximately halfway through this 3-month delivery period. This discrepancy is considered to be the result of a lack of resolution; that is, the smallest time unit in the relevant schedule is 3 months. Procurement of these components should therefore be updated for future U.S. deployment. Material order for these components, which occurs 15 months prior to the beginning of site preparation work during the COL review phase, may be required to occur even sooner to prevent these activities from delaying the critical path.

Also, the suitability of available transportation methods is uncertain. The total weight is given for the large modules, but many of these modules will be assembled on-site. The shipping weight of individual pieces is not provided. However, the RPV vessel and its internals are shipped fully assembled. The RPV and its internals weigh approximately 895 MT, and were shipped by barge for K-6. A brief investigation revealed that the maximum allowable weight for road and rail shipping is approximately 35 MT and 140 MT, respectively. Exceptions to these limits were not investigated. Therefore, it is uncertain how the RPV will be transported if an ABWR is built in a land-locked location within the U.S.

3.3. Construction

Table A-3 provides the detailed evaluation results for the ABWR construction activities. The information provided by Toshiba is considered to be reasonable. In general, the supplied schedule information included only summary-level activities. The schedule did not contain detailed activities, nor did the supporting text contain further explanations of the summary-level activities. However, it was assumed that all necessary activities have been established during construction of K-6 and K-7, and scheduling information will be available for future ABWR construction projects. Therefore, the primary goal of this evaluation was to identify items that would be important for deploying future ABWR units in the U.S. compared to Japan. Toshiba provided the following construction schedule information for NOAK ABWR units built in Japan or other Asian nations:

- Master Schedule (Figure 2.5-1, Reference 2.1) – This schedule provides a high-level summary of the overall construction process from licensing to commissioning.
- ABWR Construction Milestone Schedule (Figure 2.5-2, Reference 2.1) – This schedule provides greater detail for construction activities from first structural concrete to commercial operation. Approximately 75 activities are listed in total and categorized by building. The schedule also includes limited activities for site preparation and auxiliary building construction. In general, the supporting text does not include greater detail or an explanation of scope for each activity.
- Simplified Schedule with PPM (Attachment 2, Reference 2.2) – This schedule provides details for the construction of the reactor building from the start of site preparation to the completion of the reactor building. General structural and civil activities (about eight to ten activities) are listed for each floor of the reactor building. This schedule illustrates the open-top construction method in which mechanical/electrical/I&C work is performed on lower floors in parallel with structural work on upper floors. The open-top method illustrated in this schedule is applied to all buildings.
- ABWR Construction Summary Schedule (Figure D1, Reference 2.5) – This schedule was provided in response to a request for additional information in order to further detail activities on the critical and near-critical paths. Activities in this schedule are limited to construction and testing activities. This schedule illustrates the open-top method as

applied to other buildings and provides more detailed activities for drywell installation and system testing.

Scope

Soil preparation activities include clearing and excavating. Site preparation activities include set-up and assembly of a very heavy lift crane and construction of a surface table for on-site assembly of the large RCCV modules. Other site preparation activities such as laydown area preparation, utility installation, and road construction are not addressed. Construction of temporary facilities such as office space, change facilities, and security offices are not included in the schedule. U.S. deployment may require some changes to site preparation activities such as additional laydown area (if storage requirements change) or more robust security facilities. These changes are expected to be minimal and not impact the overall construction schedule.

The provided documentation addresses the construction of four main buildings (Reactor Building, Control Building, Turbine Building, and Radwaste Building) and some auxiliary buildings. Activities for building construction include: basemat construction, civil work (floor and wall slab construction), mechanical/electrical/I&C installation, and major equipment installation. For the reactor and turbine buildings, activities also include pre-assembly and installation of large modules and installation of major equipment, components, and structures. Reference 2.2 includes floor-by-floor construction activities for the reactor building which illustrate the open-top construction method. General mechanical/electrical/I&C installation proceeds on lower floors while floor and wall slab construction proceeds on higher floors. Construction proceeds in a similar cascading manner using the open-top method for all other buildings. The scope of building construction activities for U.S. deployment is not expected to be significantly different than during construction of K-6 and K-7.

Duration

The schedule provides four months for site clearing and grading, and nine months for excavation. The total construction and equipment installation durations for the primary buildings are:

- Reactor Building – 30 months
- Control Building – 32 months
- Turbine Building – 40 months
- Radwaste Building – 29 months

The building construction durations are considered to be accurate, since they are based on actual durations achieved during construction of K-6 and K-7. For U.S. deployment, the durations may be affected indirectly by infrastructure, work schedule, or regulatory differences. For example, differences in procurement lead times or in labor availability may slow construction or otherwise alter the currently planned durations. Also, it is uncertain whether sufficient time has been allotted in the schedule for ITAAC inspections and resolutions, which will be required for U.S. deployment.

Logic

The logic for ABWR building construction combines the open-top construction method with the use of modules which have been pre-fabricated and assembled either on-site or off-site. In general, work proceeds in a bottom-up fashion for each building. Construction begins with the basemat for each building. The floor and wall slab are then installed for each floor, and equipment and materials are set in place using cranes. Mechanical/electrical/I&C installation commences in parallel on lower floors. For the reactor building, the 5 RCCV large modules are assembled on-site (one to two months each) before being lifted into place and installed (one month each). Installation of other major equipment, such as the drywell structure, RPV, and fuel pool liners, also progresses in a bottom-up manner. All equipment and components are lifted into place before construction of the final wall and roof slab. Construction of the other buildings also progresses using the open-top method, but uses less large modules. The building construction logic is assumed to have been well-developed during construction of K-6 and K-7, and is not expected to require any changes for U.S. deployment.

3.4. Start-up and Commissioning

Table A-4 provides the detailed evaluation results for the ABWR start-up and commissioning activities. The information provided by Toshiba is generally considered to be reasonable. The provided schedule addresses start-up and commissioning activities on a summary-level only, without specific details. Commissioning of K-6 involved performing a total of 75 start-up tests (Reference 2.2), although further details of the testing were not provided. Test activities for construction of future ABWR units are scheduled for each building, without detailing specific systems involved. The control and radwaste building schedules include three to four months for electrical testing. For the control building, this electrical test is followed by a two-and-a-half-month test of the Safety System Logic and Control (SSLC), the automated digital control system network. These tests lead to a six-and-a-half-month pre-operational test period common to all buildings. This pre-operational test period overlaps the latter half of the turbine and generator installation, since testing will identify necessary adjustments. These tests should be well-developed from past construction efforts. However, the provided documentation did not provide the details necessary to evaluate whether the schedule durations were sufficient.

The provided documentation addressed fuel loading as a milestone, rather than an activity. As such, no duration for fuel loading was given. Also, final commissioning tests were not listed individually. The start of fuel loading marks the end of the pre-operational test period and the beginning of the start-up test period, scheduled for 7 months. For the K-6 and K-7 units, this start-up test period required approximately 9.5 and 9 months (Reference 2.3), respectively. This neglects an additional 2-month delay in the start-up testing of K-6, due to trouble from a fuel leak. Following construction of the Kashiwazaki units, a schedule study was conducted by Toshiba and TEPCO to evaluate the expected start-up test durations for future NOAK ABWR plants. The proposed 7-month duration is based on this study and results in an aggressive schedule, but with some contingency time. Start-up testing will require 14-hour shifts for 6 days per week and provides approximately 2 weeks for contingency time.

3.5. Training

Table A-5 provides the detailed evaluation results for the ABWR training activities. The documentation provided by Toshiba lists total durations (Reference 2.5) and relative start/end dates for operator training. From this information, operator simulator training will require 26 weeks. Simulator training will take place during the pre-operational test period and will be completed by the beginning of start-up testing and final commissioning, similar to past ABWR projects. During construction of K-6 and K-7 (Reference 2.3), an ABWR simulator was developed and installed at the BWR Operator Training Center Corporation in Japan. Operator training began prior to pre-operational testing, but the total duration was not specified.

Future ABWR construction will benefit from the training procedures and simulator development completed for K-6 and K-7. However, further effort will be required for U.S. deployment. Training procedures and control software will require translation. In addition, significant work may need to be performed if differing regulatory environments or alternate implementation methods require significant changes to the control logic or training procedures. Required activities for revising and/or developing ABWR training procedures and simulator design should be identified, in order to determine whether the currently planned simulator durations are adequate for future U.S. deployment. It is expected that these activities can be performed in parallel with other construction efforts without causing delay.

3.6. Post-COL Licensing and ITAAC

In the provided documentation (References 2.2 and 2.5), Toshiba stated that the NRC had identified 1,422 ITAAC requirements necessary for U.S. licensing of the ABWR (per 10 CFR Part 52) and that inspections would be scheduled at the start of construction. Since past ABWR construction is limited to units built outside the U.S., for which ITAAC are not applicable, no previous experience is available for demonstrating the fulfillment of ITAAC requirements; therefore, the required inspection procedures have not been fully developed. Appendix H of Reference 2.4 contains a preliminary examination of the applicability of existing NRC Inspection Procedures (IPs) in demonstrating fulfillment of these ITAAC criteria for the ABWR. From this preliminary examination, approximately 16% (233) of the ITAAC criteria could be fulfilled through use of existing IPs. 69% (975) of the ITAAC would require minor revisions to existing IPs. 15% (214) of the ITAAC would require major revisions to existing IPs or development of new IPs. The NRC is continuing to develop its inspection program and requirements, which may result in more differences than initially estimated. An updated schedule for U.S. deployment should include engineering activities necessary to develop applicable ITAAC inspection procedures, inspection activities to demonstrate fulfillment of ITAAC criteria (both on-site and off-site), and contingency float time to allow for resolution of non-conforming criteria.

4. Impact of Modularization

Toshiba plans to apply modularization to critical path activities to reduce construction times for the ABWR. Since the critical path is the reactor building, modularization will figure highly there. In addition, modularization is planned for areas that will require large amounts of mechanical and electrical commodities that may become critical path if delayed.

The types of modules planned for the ABWR are based on experience gained in ABWR construction in Japan. The modules are similar to those described in the GE ESBWR section, but the ABWR literature lists the following additional modules:

- Cable tray modules,
- Large bore piping modules, and
- Large equipment modules (e.g., the condenser).

The RCCV modules are the most important features for maintaining the ABWR schedule. These are modules for: the central mat, the RCCV lower shell, the RCCV diaphragm floor, the DEPSS, and the top slab. Like the other designs, the ABWR construction schedule relies on modularization for shorter durations.

5. CRITICAL PATH EVALUATION

The construction milestone schedule provided by Toshiba identifies the main critical path and two subcritical paths. This schedule provides only summary-level activities, with minimal details included in the supporting text. The main critical path is the construction and commissioning of the reactor building, which spans 43 months and contains 12 major activities. The main critical path includes activities during the 36-month construction period from first concrete to fuel load and a 7-month start-up test period for final reactor commissioning following fuel load. The first subcritical path is construction of the turbine building, which spans 38 months and contains 9 major activities. The second subcritical path is testing of the main control building and control room, which contains 2 major activities over 6.5 months. The critical and subcritical paths include construction and commissioning activities, but do not include procurement or site preparation activities. The construction and commissioning activities on the critical and subcritical paths are considered reasonable, within the scope of information provided by Toshiba.

Main Critical Path: Reactor Building Construction

The critical path begins with assembly and installation of the reactor building basemat over a three-month period. The basemat rebar is assembled onsite, and then lifted into place before concrete is poured. During this time, the RCCV modules and other large modules are assembled onsite. Once the RCCV Lower Shell module is completely assembled, it is lifted into place and installed. The critical path activities then become civil work to erect the floor and wall slabs of the reactor building over a period of 17 months, to a specified elevation required for installation of the RPV. Throughout this period, other large modules are installed. However, only the installation of the RCCV Upper Shell module and of the Top Slab module are considered critical path. It should be noted that RPV installation is kept off the critical path. Following this civil work, the critical path then becomes installation of the pool liner modules (four months), followed by upper structural steel work (two months). The critical path then proceeds to installation of the remaining wall and roof (two and a half months). Once the roof is constructed, the latter part of the reactor building crane installation then becomes critical path. When the crane becomes available, the critical path becomes pre-operational (six and a half months) and start-up testing (seven months), which lead to commercial operation.

Perimeter civil work, lower drywell work, and the installation of other large modules not called out above are kept off the critical path. Also, mechanical/electrical/I&C activities and installation activities for the RPV internals do not become critical path.

Subcritical Path No. 1: Turbine Building Construction

The Turbine Building subcritical path begins with construction of the basemat over a two-and-a-half-month period. The Turbine/Generator Pedestal Column is then installed, which requires approximately six months. The subcritical path then becomes condenser installation (two and a half months), before proceeding to installation of the Turbine/Generator Pedestal Deck (three months). Civil work to erect floor and wall slabs, which has been proceeding since completion of the basemat, then becomes subcritical path until finished (five months). The turbine subcritical path then proceeds with installation of the final structural steel (three and a half months) and the remaining wall and roof (two months). The next subcritical path item becomes installation of the turbine building crane, which requires approximately one and a half months. The subcritical path then becomes final installation of the turbine and generator, which occurs over the 12 months remaining until fuel load. This subcritical path has an available float of approximately two weeks before becoming critical path (Reference 2.5).

Civil work is not subcritical path until installation of the pedestal deck is complete. Although installation of the first condenser is subcritical path, remaining condenser installation work remains off the subcritical path. Also, mechanical/electrical/I&C installation and pre-operational testing activities are kept off the turbine building subcritical path.

Subcritical Path No. 2: Control Building and Main Control Room Testing

Control Building subcritical path activities include testing requirements necessary to prepare the control building for system-wide pre-operational tests. The subcritical path begins with a four-month electrical test of the control building and main control room. The path then proceeds to a two and a half month electrical test of the SSLC digital system of the main control room. This test completes the control room subcritical path and leads to pre-operational testing. This subcritical path has an available float of approximately two weeks before becoming critical path (Reference 2.5).

6. First-Versus Nth-of-a-Kind

There is no significant difference between construction of the 1st and Nth ABWR units (Reference 2.1). The 1st unit requires a Structural Integrated Test (SIT) to measure strains in the containment structure. The 1st U.S. ABWR, although the Nth unit overall, will also require a SIT since the rebar configuration in the RCCV has changed since K-6. This requires a few weeks for instrument installation, but is not on the critical path. Therefore, the overall schedule for the 1st and Nth units in the U.S. is not expected to be considerably different.

7. SUMMARY OF VENDOR RISK ASSESSMENT BY VENDOR

Previously in 1997, GE performed a risk assessment of the ABWR schedule to support NRC Design Certification. However, the initial 1997 prototype ABWR schedule is significantly different from the schedule achieved at K-6 and the current schedule proposed by Toshiba. Therefore, the initial ABWR risk assessment results from GE are considered inapplicable.

Furthermore, Toshiba has not performed a risk assessment study for the current ABWR construction activities, since it is their position that sufficient experience and information has been gained from past construction of ABWR units.

Table A-1. Toshiba ABWR Schedule Evaluation
Engineering Phase

Activity	Scope	Duration	Logic
A. Conceptual and Preliminary Design			
Discipline Specific	Design certification for the U.S. version of the ABWR design was received from the U.S. Nuclear Regulatory Commission in May 1997. Although conceptual and preliminary design activities are not included in the schedule, it is assumed that these activities are largely complete based on the certification of the ABWR design and the fact that similar ABWR units have already been built and are operating in Japan. The site-specific conceptual and preliminary design activities will need to be performed and should be included in the schedule. A simplified ABWR site plan was included in the documentation but this would need to be revised significantly based on the actual site selected for construction.	The durations for conceptual and preliminary design activities for the U.S. version of the ABWR are not discussed in the documentation. The ABWR provides 27 months for COL and 33 months for ESP (if required) licensing activities, which are expected to include site-specific engineering activities. Compared to the time allocated for pre-construction design and licensing activities for other reactors, these ABWR licensing durations are considered sufficient to allow inclusion of site-specific preliminary engineering activities.	N/A
Simulator	Activities related to preliminary simulator design are not discussed in the documentation. It is assumed that preliminary simulator design is complete, based on previous construction of the K-6 and K-7 ABWR units.	Additional simulator preliminary design prior to U.S. deployment is not expected to affect the overall construction schedule.	N/A

Activity	Scope	Duration	Logic
B. Detailed Design			
Discipline Specific	Design certification for the U.S. version of the ABWR design was received from the U.S. Nuclear Regulatory Commission in May 1997. Although detailed design activities are not included in the schedule, it is assumed that these activities are largely complete based on the certification of the ABWR design and the fact that similar ABWR units have already been built and are operating in Japan. A large amount of detailed design information was provided in the documentation, including general arrangement drawings for the three main buildings, electrical one-line diagrams, equipment lists, and piping line lists. The site-specific detailed design activities will need to be performed and should be included in the schedule.	The durations for detailed design activities for the U.S. version of the ABWR are not discussed in the documentation. The ABWR provides 27 months for COL and 33 months for ESP (if required) licensing activities, which are expected to include site-specific engineering activities. These durations are considered sufficient to allow for site-specific engineering activities. Compared to the time allocated for pre-construction design and licensing activities for other reactors, these ABWR licensing durations are considered sufficient to allow inclusion of site-specific detailed engineering activities.	N/A
Simulator	Activities related to detailed simulator design are not included in the schedule. It is assumed that simulator detailed design is well-established, based on previous construction of the K-6/K-7 ABWR units. The supporting text (Ref. 2.5) included a single activity for simulator design, manufacture, and procurement.	Final simulator design activities, manufacture, and procurement are scheduled for 78 weeks. This duration is considered acceptable when considering experience gained during construction of K-6 and K-7. Simulator design activities may be started earlier than currently scheduled, if necessary, to prevent possible delays.	Simulator design and procurement commence approximately 10 months after first concrete, although there is no predecessor which prevents earlier commencement. The simulator is delivered and installed following installation of the main control room. This logic is considered acceptable.

Activity	Scope	Duration	Logic
Modules	The ABWR construction identifies 13 large modules applied to the critical path activities and approximately 130 modules applied to the subcritical path activities. Design activities for these modules were not addressed in detail. From the supporting text (Ref. 2.5), module design will require approximately 1 year prior to construction. These design activities are due to the increased, and as yet undeveloped, modularization planned for future ABWR units. The scope of these design activities was not discussed, nor was the exact number of new modules addressed. Compared to K-6, almost all of the large modules in the RCCV for future construction have been altered. The extent to which they have been developed, such as for plants currently under construction, is uncertain. Modular construction methods have been applied to all past ABWR units, and future ABWR units will be NOAK. Therefore, the detailed design of the modules is assumed to be very well developed, with the exception noted above. Not including additional module design activities in the schedule is acceptable since these activities can be performed prior to the start of construction and will not change significantly for U.S. deployment.	The documentation did not provide the number of new modules that need to be developed, nor the degree of development that is required. Therefore, the 1-year duration cannot be evaluated. However, the exact duration can be adjusted, to a degree, by assigning additional staff. Therefore, the duration is considered reasonable and achievable.	The module design activities occur prior to the start of construction, although the exact start is not specified. This logic is considered reasonable, provided design activities are completed early enough for long-lead items such as the RCCV modules. This may require that design activities commence prior to the start of the COL review.

Table A-2. Toshiba ABWR Schedule Evaluation
Procurement Phase

Activity	Scope	Duration	Logic
A. Component Procurement			
Long-Lead Items	Lead times are provided for the RPV and the RCCV shell liners. The documentation addresses no other long-lead items. For major component procurement, Toshiba provided a list of vendors used in the construction of ABWR units in Japan.	The durations shown on the schedule for procurement of the long-lead items are as follows (from material order to ship date): RPV - 3 yrs 9 months RCCV shell liner modules - 2 yrs These durations are considered reasonable since they are based on the actual lead times for K-6 and K-7.	Material order for both the RPV and RCCV modules occurs 15 months prior to site preparation work, during the COL review process. RCCV modules do not have separate delivery times called out, but are shown to arrive before on-site assembly begins. The RPV has a separate delivery period of 3 months. However, the RPV installation commences approximately 1 month into this delivery period. This discrepancy is assumed to be due to a lack of resolution on the master schedule, i.e., the smallest time unit on the schedule in question is 3 months. Additional lead time may be required for alternate sites, since these activities are critical path.
Bulk Materials	Activities related to procurement of bulk materials are not included in the schedule. However, Toshiba does provide a list of some of the vendors used in the construction of ABWR units in Japan. Unlike other equipment and major components, bulk materials are expected to be purchased locally to reduce transportation costs. New bulk material vendors would therefore be desired for U.S. deployment of the ABWR.	N/A	N/A

Activity	Scope	Duration	Logic
Shop-Testing and Qualification	Activities related to shop-testing and qualification of components are not included in the schedule. Shop-testing and qualification procedures and activities are expected to have been fully developed during construction of K-6 and K-7. These procedures are not expected to be significantly different for future ABWR units, unless changes are required by differing regulatory environments.	N/A	N/A
Transportation	Transportation means and methods were not included in the information provided by Toshiba. Also, since no specific site was assumed, the transportation methods and means cannot be specified. Transportation activities will need to be updated and incorporated into the schedule for future U.S. deployment.	The durations for transportation of components and bulk materials are not discussed in the information provided by Toshiba. No specific site was assumed, and the transportation durations will be dependent on the site. Transportation durations will need to be calculated and incorporated into the schedule for future U.S. deployment.	N/A
B. Module Fabrication and Assembly			
Shop Fabrication and Assembly	The Toshiba documentation identifies 13 large modules applied to the critical path activities. These range up to 1050 MT in weight and 42 m in diameter. Included are the central mat rebar and anchor bolts, RCCV shell, RPV, spent fuel pool liners, and others. For sub-critical path activities, approximately 130 modules are expected. These include large bore piping, cable trays, condenser, equipment skids, and others. It is expected that all fabrication and assembly activities have been fully developed in the construction of K-6 and K-7. These activities are not expected to differ significantly for future U.S. deployment.	The durations for shop fabrication and assembly of modules for the U.S. version of the ABWR are not discussed in the documentation. These durations are not expected to differ significantly for future U.S. deployment.	N/A

Activity	Scope	Duration	Logic
Shop-Testing and Qualification	Shop-testing and qualification of modules are not discussed in the documentation. It is expected that all testing and qualification activities have been fully developed in the construction of K-6 and K-7. These activities are not expected to differ significantly for future U.S. deployment, unless changes are required due to differing regulatory environments.	N/A	N/A
Transportation	Toshiba's documentation states the rationale used to determine the appropriate division of on-site/off-site work for module construction and manufacturing of large components. A major influence in making this decision will be the location of the site and the cost of transportation, but specific transportation methods are not included in the documentation. Module transportation activities will need to be updated and incorporated into the schedule for future U.S. deployment.	In general, the transportation durations for modules are not discussed in the documentation. However, delivery of the RPV module is shown on the master schedule with a duration of 3 months. See the above "Component Procurement/Long Lead Items" for a discussion of the RPV module. No specific site was assumed in the ABWR documentation, and the transportation durations will be dependent on the site and the means of transportation used. Module transportation durations will need to be calculated and incorporated into the schedule for future U.S. deployment.	N/A

Activity	Scope	Duration	Logic
On-site Fabrication and Assembly	For the large modules on the critical path activities for reactor building construction, the approach will be ground assembly on the table surface on-site. This is necessary because of the size (up to 42 m diameter) and weight (up to 1050 MT) of the assembled modules. The RPV module and RPV internals will be pre-assembled at the factory and shipped as one module. For the majority of the modules applied to sub-critical path activities, the approach for on-site/off-site activity will be judged for each module according to the cost difference between on-site/off-site, such as additional transportation costs due to larger size and/or weight.	The durations for on-site fabrication and assembly are not provided, with the exception of a 6-month duration shown for the RCCV liners. However, the durations for module installation are provided for some of the largest modules used in critical path activities for reactor building construction, as shown below. Base Mat Module - 11 days RCCV Lower Shell Module - 10 days Diaphragm Floor Module - 34 days RCCV Upper Shell Module - 22 days Drywell Module - 33 days Top Slab Module - 23 days Pedestal Module - 22 days	For the large module installations included in the construction schedule, the installation start dates suggest that only one module at a time need be assembled on-site. One month or more is provided between completing installation of one module and beginning installation of the next. This logic is judged to be reasonable.

Table A-3. Toshiba ABWR Schedule Evaluation
Construction Phase

Activity	Scope	Duration	Logic
A. Site Preparation			
Soil Preparation	The schedule provides for clearing, grading, and excavation. Drainage considerations are not explicitly called out, but are expected to occur in conjunction with other soil preparation activities.	The durations given for soil preparation are: Clearing & Grading – 4 months Excavation – 9 months These durations are considered to be reasonable, compared to the durations of K-6 and K-7 and the durations scheduled for other advanced reactors.	Clearing and grading commence after a LWA is granted and precede excavation. Soil preparation is completed before major construction begins. However, some work on laydown areas, mats, and entrenched pipes overlaps with the final stages of soil preparation. This logic is reasonable.
Laydown Area Preparation	The provided documentation does not include the scope, duration, or sequence of laydown area preparation activities. Procurement will follow a "just-in-time" delivery schedule, which will minimize the required laydown and storage areas. It is expected that these activities have been developed during K-6 and K-7, but may require updating to account for differing transportation and lead times.	N/A	N/A
Storage Area Construction	The provided documentation does not include the scope, duration, or sequence of activities for temporary or permanent storage area construction. It is expected that these activities have been developed during K-6 and K-7, but may require updating to account for differing transportation and lead times.	N/A	N/A
Equipment Assembly Area	The schedule does not call out time for most of the equipment and module assembly areas. Surface table preparation is included in the provided schedule for the RCCV modules. This scope is judged to be sufficient for the large modules.	The schedule provides approximately one month each for the construction and removal of the RCCV module assembly area. This duration is considered reasonable.	Preparation of the surface table for RCCV module assembly precedes module construction activities. Removal of the surface table occurs after RCCV module installation is complete. This logic is reasonable.

Activity	Scope	Duration	Logic
Road & Rail Construction	The provided documentation does not include the scope, duration, or sequence of activities for temporary or permanent storage area construction. It is expected that these activities have been developed during K-6 and K-7, and will not be significantly different for future U.S. deployment.	N/A	N/A
Security Construction	The provided documentation does not include the scope, duration, or sequence of activities for temporary or permanent security facilities. It is expected that these activities have been developed during K-6 and K-7, and will not be significantly different for future U.S. deployment.	N/A	N/A
Temporary Office Space and Services	The provided documentation does not include the scope, duration, or sequence of activities for temporary offices and facilities. It is expected that these activities have been developed during K-6 and K-7, and will not be significantly different for future U.S. deployment.	N/A	N/A

Activity	Scope	Duration	Logic
B. Building Construction			
Reactor Building (Containment Vessel, Shield Building)	Construction of the reactor building is the main critical path for the ABWR. The first activity is assembling and installing the basemat module. Construction of the RCCV consists of the successive installation of RCCV modules, which have been previously assembled on site. The reactor building itself proceeds floor-by-floor. Equipment, piping, and other civil work also proceeds floor-by-floor, beginning with the installation of the next floor slab. The RPV is then lifted into place prior to construction of the last wall and roof. This scope is considered sufficient.	The total duration for construction of the reactor building (not including testing) is 30 months. Basemat assembly and installation requires 4 months. Construction of each floor slab and wall requires approximately 4 months total, with some overlap between floor and wall construction. Equipment, piping, ventilation, and electrical work on each floor requires approximately 10 – 15 months. Following on-site assembly, installation of each RCCV module into the reactor building is scheduled for approximately 1 to 2 months. The RPV is shipped from the factory with the RPV internals pre-assembled. Additional on-site assembly and installation of the internals is given 9 months in the schedule. These durations are considered reasonable.	The basemat assembly precedes further reactor building activities. A slight overlap occurs between construction of each floor slab and wall, which is considered necessary. Construction proceeds floor-by-floor, with piping, etc., occurring in parallel with the construction of upper floor slabs and walls. Also, equipment, piping, etc., activities shorten in duration for the higher floors and when piping and cable tray modules are employed. Installation of the RPV consists of a significant amount of time dedicated to the RPV internals. The internals are pre-assembled into the RPV at the factory, before shipment to the site. Therefore, this time is expected to be used mainly for hook-up activities, with minimal on-site installation of RPV internals into the vessel. This logic is reasonable for the open-top construction method.
Auxiliary Building	The ABWR does not contain an Auxiliary Building.	N/A	N/A
Turbine Building	Turbine building construction begins with basemat and buried CCW piping installation. Construction and installation of the pedestal column, condenser modules, and pedestal deck proceed next, in parallel with the open-top floor-by-floor building construction. Installation of the structural steel modules and the final wall and roof occur next. Construction then proceeds through installation of the turbine building crane, turbine, and generator. This scope is considered sufficient.	The overall duration for turbine building construction is 40 months, from start of basemat through complete installation of the turbine and generator. Building civil work, structural steel, and final wall and roof construction requires 23 months. Installation of the crane, turbine, and generator requires 13.5 months total, with a short overlap with civil work. Both civil work and turbine installation are overlapped by 16 months of equipment, piping, cable, and instrumentation installation. These durations are considered reasonable.	Although floor-by-floor details are not provided, construction of the turbine building precedes bottom-up using the open-top construction method. It is expected that the initial civil work period consists of floor slab and wall construction for lower floors. Installation of equipment, piping, etc., on lower floors proceeds in parallel with floor slab and wall installation on the upper floors. The turbine crane is installed following the completion of structural steel installation, but before installation of the final roof slab. The crane is available for the turbine and generator installation, which occurs in parallel with preoperational tests. Fill around the turbine building does not commence until the circulating water piping is laid. This logic is considered to be reasonable.

Activity	Scope	Duration	Logic
Radwaste Building	Construction of the radwaste building begins with basemat installation. Civil work follows. After an initial period of civil work, installation of equipment, piping, cable, and instrumentation occurs in parallel with the remaining civil work. This scope is considered sufficient.	The total duration for construction of the radwaste building is 29 months, from start of basemat construction to completion of equipment, piping, etc., installation. This duration is considered to be reasonable.	Although floor-by-floor details are not provided, construction of the radwaste building proceeds bottom-up using the open-top construction method. This approach is consistent with the initial delay, and the eventual overlap, between civil work and equipment, piping, etc., installation. This logic is considered reasonable.
Diesel Generator Building	The Diesel Generator facilities are located within the Reactor Building. As such, the ABWR does not have a separate Diesel Generator Building.	N/A	N/A
Annex Building	The provided documentation describes an annex building (referred to as a Service Building) for personnel facilities, security offices, and a health physics station. However, the provided schedule does not include construction activities, durations, or sequences for the Service Building. It is expected that these activities have been developed during K-6 and K-7, and will not be significantly different for future U.S. deployment.	N/A	N/A
Main Control Building	The schedule provides time for construction of the Main Control Building, beginning with basemat placement. This is followed by initial civil work, which overlaps with equipment, piping, ductwork, and electrical work. This scope is considered adequate.	The total duration for control building construction is 32 months, from start of basemat to completion of M&E/I&C work. Civil work is scheduled for 19 months. Equipment, piping, etc., installation is given 24 months, with 6 months dedicated to the main control room. These durations are considered reasonable, since they are based on actual durations achieved during construction of K-6 and K-7.	Basemat installation precedes other construction activities. The schedule does not contain floor-by-floor activity details. However, civil work proceeds for 6 months prior to equipment and piping installation. This initial period is expected to include floor and wall construction, and construction is expected to proceed floor-by-floor using the open-top method, similar to the reactor building. The main control room is assembled prior to electrical and start-up testing. This logic is considered reasonable.
Administration Building	The provided documentation does not include the scope, duration, or sequence of activities for administration building construction.	N/A	N/A

Activity	Scope	Duration	Logic
Circulating Water Building	Although lacking detail, the schedule does provide time for construction of the circulating water building, buried piping, and cooling towers. This scope is considered to be adequate	The durations for various activities are: Building Construction – 6 months Buried Pipe Installation – 4 months Cooling Tower Construction – 10.5 months These durations are considered reasonable, since they are based on actual durations achieved during K-6 and K-7.	No time is explicitly provided for the circulating water building basemat. Fill around the turbine building proceeds after installation of buried Circulating Chilled Water (CCW) piping. Cooling tower construction includes refurbishing an existing cooling tower, and construction of an additional tower. No explanation is provided for why an existing cooling tower is assumed, although it is most likely due to the specifics of construction at K-6 and K-7. This will require revision prior to U.S. deployment.
Transformers and Switchyard	The provided schedule includes construction durations for transformers and switchyards, but the supporting text does not contain further detail or explanation. It is expected that these activities have been developed during K-6 and K-7, and will not be significantly different for future U.S. deployment.	The schedule provides 6 months for construction of an auxiliary transformer facility (161 kV) and 9.5 months for construction of other transformer facilities (500 kV). These durations are considered reasonable since they are based on actual durations achieved during past construction of K-6, and are not expected to differ significantly for U.S. deployment.	Construction of the auxiliary transformer facility begins during the latter part of the overall project, following completion of the CCW building and piping. At the completion of the auxiliary transformer facility, 161 kV power is received by the other buildings, which occurs prior to qualification testing. Construction of other transformer facilities has no predecessor, but begins during the latter half of the auxiliary transformer construction. Construction is completed prior to the start of fuel loading and commissioning. This logic is considered to be reasonable.

Activity	Scope	Duration	Logic
C. System Completion and Turnover			
Transformers and Switchyard	The provided schedule lists some testing activities, but does not detail the scope, duration, or sequence of the tests to be performed. In addition, most of the testing is assumed to be system qualification tests rather than system turnover tests. From the supporting text (Ref. 2.5), most system turnover activities are included within the construction durations and occur as soon as each system is completed. These tests include flushing and cleaning of pipes, hydrostatic testing, initial calibration, electrical checks, and initial equipment energization. It is expected that system turnover activities have been developed during K-6 and K-7, and will not be significantly different for future U.S. deployment.	The durations for system turnover activities are not called out separately in the provided documentation. However, these durations are expected to be well-developed from past projects, and not expected to change significantly for U.S. deployment.	N/A
Reactor Systems			
Safety Systems			
Turbine Generator Systems			
Main Control Room Systems			
Simulator			
Radwaste Systems			
Electrical Systems			
Water Treatment Systems			
Other Plant Systems			

Table A-4. Toshiba ABWR Schedule Evaluation
Start-up and Commissioning Phase

Activity	Scope	Duration	Logic
A. System Testing and Qualification			
Transformers and Switchyard	The provided documentation does not include testing or qualification activities for the transformers and switchyards. Required qualification tests and procedures are assumed to have been developed already during construction of K-6 and K-7.	N/A	N/A
Reactor Systems	The schedule provides time for a general pre-operational test period of the reactor system. Hydro-testing of the RPV is called out as a milestone on the schedule. Specific tests are called out in Reference 2.5. The supporting text does not provide further detail concerning the scope, duration, sequence, or other systems involved in these tests. The required qualification tests are not expected to be significantly different from those carried out at K-6 and K-7, unless additional or alternate tests are required due to differing regulatory environments.	The overall pre-operational test period is scheduled to take 6.5 months. This duration is considered reasonable, as it is similar to the actual pre-operational test period of K-6 and K-7.	The reactor building receives power prior to commencement of pre-operational testing. Also, all major construction activities are finished by the start of pre-operational testing. Testing occurs in parallel with other system testing and in parallel with the final half of the turbine and generator installation. Pre-operational testing is followed by fuel loading and start-up testing. This logic is considered reasonable.
Safety Systems	The provided documentation does not include activities specifically for safety systems. However, the control building testing includes a period for electrical testing of the Safety System Logic and Control (SSLC), the digital data acquisition and control system for the ABWR. A description of the electrical test and/or further detail is not provided in the documentation.	The schedule provides 2.5 months for the SSLC electrical test.	The SSLC test is preceded by electrical testing of the control building and main control room. The SSLC test begins when the control building receives power. It is followed by the general pre-operational testing period. This logic is considered to be reasonable.

Activity	Scope	Duration	Logic
Turbine Generator Systems	The schedule includes pre-operational testing of the turbine and generator systems. Testing occurs concurrently with the reactor system pre-operational tests. The schedule in Reference 2.5 includes a detailed test breakdown, which identifies specific tests. The supporting text does not provide further detail of the scope, duration, sequence, or other systems involved in these tests. The required qualification tests are not expected to be significantly different from those carried out at K-6 and K-7, unless additional or alternate tests are required due to differing regulatory environments.	The overall duration scheduled for turbine and generator testing is 6.5 months.	Turbine and generator testing follows all turbine building construction activities, with the exception of turbine and generator installation. Rather, testing occurs in parallel with the latter half of turbine installation. This is reasonable, since the turbine and generator installation will be adjusted as necessary based on the results of system tests. Testing is followed by commissioning and ascent to power, which requires all systems to be operational.
Main Control Room Systems	The schedule includes an electrical test of the control building and main control room systems. This test is followed by an electrical test of the SSLC (see “Safety Systems” above). The schedule in Reference 2.5 includes sub-tasks for these test periods. A description of tests and/or further detail is not provided in the documentation.	Control room electrical testing is scheduled for 4 months prior to receiving power, and an additional 2.5 months for an SSLC electrical test after receiving power.	Testing of the main control room systems occurs in parallel with installation of the RPV, turbine, generator, and other construction activities including control building civil work. Testing begins following the completion of the control building civil work and the main control room. Electrical testing of the control room is followed by the SSLC electrical test, which then leads to pre-operational testing of the reactor building. This logic is considered reasonable.
Simulator	The provided documentation does not include activities for the simulator. Therefore, testing and qualification of the simulator was not evaluated. Required qualification tests and procedures are assumed to have been developed already during construction of K-6 and K-7.	N/A	N/A

Activity	Scope	Duration	Logic
Radwaste Systems	The schedule provides time for electrical tests and pre-operational tests of the radwaste systems prior to fuel loading. The documentation does not provide further detail of the scope, duration, sequence, or other systems involved in these test periods. The required qualification tests are not expected to be significantly different from those carried out at K-6 and K-7, unless additional or alternate tests are required due to differing regulatory environments.	Prior to system turnover, the schedule provides 3 months for electrical tests, followed by 5 months for pre-operational tests of the radwaste systems.	Testing activities begin following completion of civil work and installation of equipment, piping, etc. The radwaste building receives power approximately halfway through the electrical testing, prior to pre-operational testing. The majority of this testing occurs in parallel with the reactor system pre-operational testing, and is followed by fuel loading. This logic is considered reasonable.
Electrical Systems	The schedule does not provide for generic electrical system testing, but does provide for electrical testing of the main control room, SSLC, and radwaste building, which are discussed above. Required qualification tests and procedures are assumed to have been developed already during construction of K-6 and K-7.	N/A	N/A
Water Treatment Systems	The provided documentation does not include activities for the water treatment systems. Therefore, testing and qualification of these systems was not evaluated. Required qualification tests and procedures are assumed to have been developed already during construction of K-6 and K-7.	N/A	N/A
Other Plant Systems	The provided documentation does not include activities for other plant systems. Therefore, testing and qualification of other systems was not evaluated. Required qualification tests and procedures are assumed to have been developed already during construction of K-6 and K-7.	N/A	N/A

Activity	Scope	Duration	Logic
B. Fuel Loading			
Fuel Loading	Fuel loading is addressed in the documentation as a milestone, rather than an activity. It is assumed that all fuel loading procedures and activities have been established already in the construction of K-6 and K-7.	No duration was provided anywhere in the documentation for fuel loading.	Fuel loading is preceded by pre-operational testing, and is followed by start-up testing. Without further detail, this logic is considered reasonable.
C. Final Commissioning			
Final Commissioning	Specific testing and final commissioning activities are not included in the provided documentation. The provided schedule does include a start-up test period between the start of fuel loading and commercial operation. During this period, 75 separate start-up tests will be performed. Details concerning the scope, durations, sequence, and systems involved in the tests are not provided in the documentation. The required commissioning tests are not expected to be significantly different from those carried out at K-6 and K-7, unless additional or alternate tests are required due to differing regulatory environments.	The provided documentation schedules 7 months for start-up testing. This duration includes the time required for fuel loading, which is not called out separately. This start-up test period required 9.5 months during the construction of K-6, and 9 months for K-7. This neglects an additional 2-month delay caused by a fuel leak during testing of K-6. The reduction in the proposed schedule is based on a study of expected learning curve effects for NOAK units, but results in an aggressive work schedule. The proposed start-up test duration will require 14-hr shifts for 6 days per week, and includes approximately 2 weeks contingency time. The start-up test duration for future ABWR units is similar to that achieved in the past. The proposed schedule is considered aggressive, yet achievable.	All construction activities and turnover testing is completed prior to start-up testing. Start-up testing begins with commencement of fuel loading and ends with commercial operation. This logic is reasonable to the extent it can be evaluated without further details.

Table A-5. Toshiba ABWR Schedule Evaluation
Training Phase

Activity	Scope	Duration	Logic
A. Operator Training			
Operator Training	The provided documentation does not specify activities for general operator training. All operator training procedures are expected to have been established in the construction of K-6 and K-7.	N/A	N/A
B. Operator Training on Simulator			
Operator Training on Simulator	The schedule did not include activities for operator training on a simulator. However, the supporting text (Ref. 2.5) includes simulator training durations and relative start/end dates. Operator simulator training for K-6 was performed offsite at the BWR Operator Training Center Corporation. Therefore, simulator training procedures have already been established but may require revising.	The duration scheduled for operator simulator training is 26 weeks.	Simulator training was not included on the main schedule. From the supporting text (Ref. 2.5), simulator training is scheduled to begin near the start of pre-operational testing, following simulator installation and testing (SSLC testing). Simulator training is completed prior to the start of fuel loading and the final commissioning start-up tests. This logic is acceptable.

Table A-6. Toshiba ABWR Schedule Evaluation
Licensing and ITAAC Phase

Activity	Scope	Duration	Logic
A. Pre-Fuel Load			
Engineering Reviews **Module Shop Inspections** **On-site Construction Inspections** **Testing and Qualification Reviews**	The provided documentation did not detail the scope, duration, or sequence of specific ITAAC requirements or activities. However, the total number of ITAAC criteria was provided. Toshiba stated that 1422 ITAAC requirements will need to be resolved. The final number and type of ITAAC requirements is uncertain and will depend on the licensing reviews. The final requirements will need to be incorporated into the schedule prior to U.S. deployment.	N/A	N/A
B. Post-Fuel Load			
Engineering Reviews **On-site Construction Inspections**	See above.	N/A	N/A

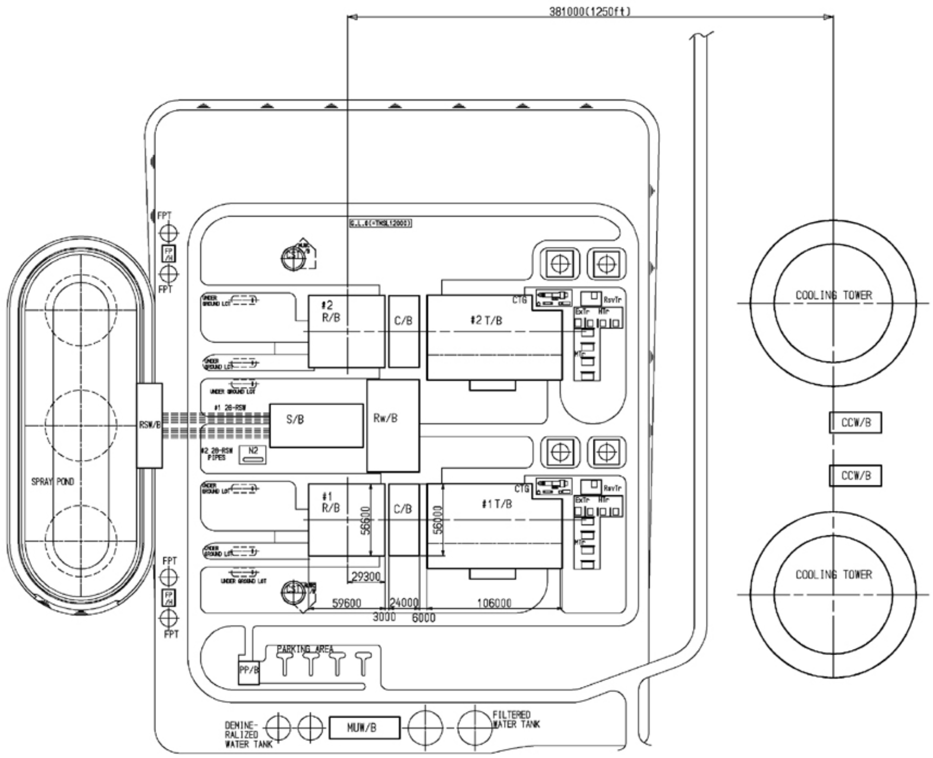

Figure A-1. Toshiba ABWR Plot Plan

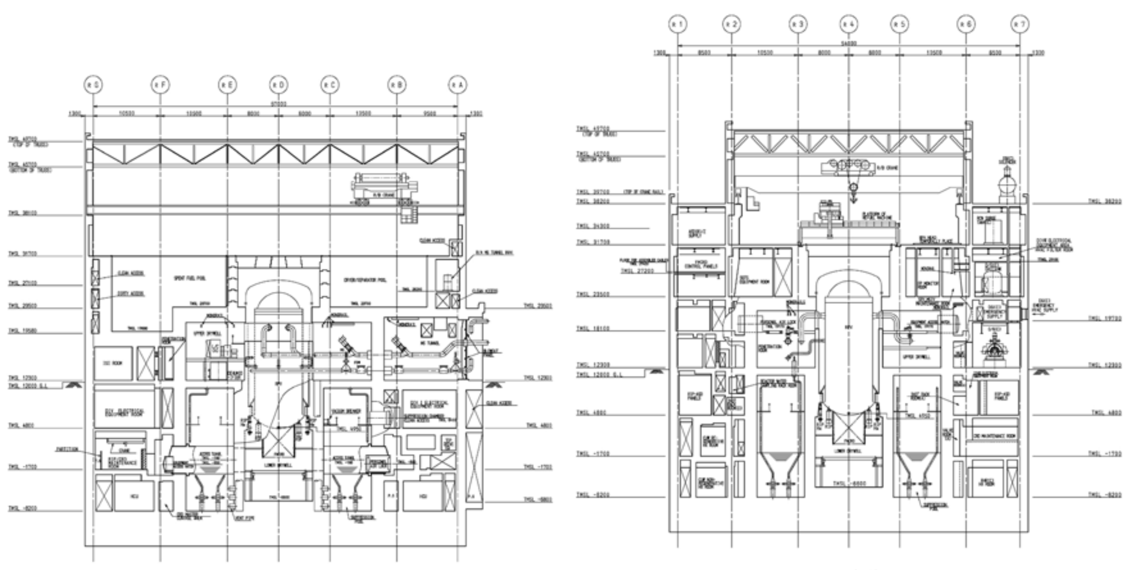

Figure A-2. Toshiba ABWR Reactor Building
(Reference 2.1)

B

General Electric ESBWR

1. Background

The GE Economic Simplified Boiling Water Reactor (ESBWR) is a natural circulation boiling water reactor design that uses passive safety systems in a simplified design to produce economic nuclear energy. The ESBWR is the latest design in the evolutionary path of BWRs and uses much of the technology developed for the GE ABWR and GE SBWR.

ESBWR is in the middle of a stepwise approach to Design Certification. The pre-application approach involves getting at least two separate Safety Evaluation Reports before the submittal of the actual Design Certification Application in mid-2005. The SER will allow an expedited review of the Design Certification Document (DCD). The NRC and ACRS reviews leading to the first SER (due in April 04) of the passive safety system technology are on schedule.

As the review of the ESBWR is still in the pre-application phases, much of the detailed schedule work and construction planning has not been performed. However, since the ABWR did reach design certification and there will be extensive synergy with the ESBWR design, GE provided the construction and modularization plan information for the ABWR as a basis for the ESBWR constructability assessment. A schedule for the ESBWR exclusively was not provided. Where known deviations from ABWR durations and quantities exist, allowances were made, but this assessment should still be considered as preliminary. Within this report all information provided by GE is assumed to be pertinent to the ESBWR even if it is provided under the heading of ABWR work.

Note that the ABWR construction and modularization plan was developed with the goal of meeting the standards set by the utilities, EPRI, and DOE as described in the Advanced Light Water Reactor (ALWR) Utility Requirements Documents (URD).

1.1. Plot Plan

To orient the reader to the layout of the ESBWR, a plot plan from Reference 3.3 is provided in Figure B-1.

1.2. Systems and Equipment

The major systems and equipment of the GE ESBWR are organized by system and included below:

Reactor Building (See Figure B-2)

- Reactor Pressure Vessel
  - Fuel Core
  - Chimney
  - Steam separators / dryers
- Reactivity Controls
  - Fine Motion Control Rod Drive (FMCRD)
  - Control Rod Drive System
  - Standby Liquid Control System
- Nuclear Boiler System
  - Depressurization Valves
- Safety Systems
  - Isolation Condenser System
  - Gravity-Driven Cooling System
  - Drywell-to-Wetwell Vacuum Breakers
  - Suppression Pool
  - Passive Containment Cooling System
- Containment Over-pressure Protection System (COPS)
- New Fuel Storage Pool
- Robotic Refueling Machine
- Reactor Water Cleanup System / Shutdown Cooling System
- Fuel and Auxiliary Pool Cooling System
- Main Steam Isolation Valves (MSIV)
- Auxiliary Fuel Building
  - Spent fuel pool
  - Inclined Fuel Transfer System

Turbine Island

- Steam Turbine
- Generator
- Condenser
- Moisture Separator Reheater
- Condensate / Feedwater System
- Gland Steam Condenser
- Offgas System

Other

- Control and Instrumentation
  - Neutron Monitoring System
  - Control Room

2. SCHEDULE ASSUMPTIONS

GE established the following assumptions that influence schedule duration and construction planning.

2.1. Fundamental Project Assumptions

1. The schedule is based on a staggered rolling 4 days/10 hours schedule for 3 construction teams. Under this system, work will proceed 7 days per week, with each team working four days and taking two days off. The associated administrative staff will work 5 days per week, 8 hours per day, unless additional staffing is required for material receipts or other unusual activities. Overtime will not be considered a standard work practice, for schedule development purposes. Although this assumption may be unrealistic and overtime may ultimately be used for certain critical path activities, this assumption presents a cost risk instead of a scheduling risk and results in conservative schedule durations.
2. Labor agreements with “no strike” language will be agreed to and signed prior to construction start.
3. January 1, 2005, is selected as the reference date for the POWRTRAK™ scheduling program.

4. Lack of funding or engineering support and design changes will not impede construction progress.
5. The project will be structured using an Engineer-Procure-Construct (EPC) construction organization to manage the work.

2.2. Licensing and Permitting Assumptions

6. There will be limited NRC presence on-site during construction (6-12 persons). NRC involvement will be defined and agreed upon prior to the beginning of construction.
7. COL will be issued to the plant owner before Owner Commitment to Construct and will be received prior to first structural concrete placement in the Reactor Building basemat.
8. ITAAC implementation and all additional testing will not hinder the project delivery process other than prior to initial reactor fuel loading.
9. The owner will obtain all permits such as the ESP, COL, and all applicable state and local permits, except the local building permit. The owner will obtain the plant site and install utilities, roadway and railway access up to the site boundary.

2.3. Site-Specific Assumptions

10. The selected site will have an adequate supply of construction labor to support the work schedule and no training of skilled labor will be required.
11. Construction is based on a single unit on a new site or pre-existing plant site with no operating units in the immediate vicinity.
12. The site will have adequate space for construction facilities, subcontractor work areas, laydown space, module fabrication areas, and large mobile crane access.
13. Barge transportation is unavailable.
14. The reference site is Kenosha, Wisconsin.
15. Site is generally flat and open land and has good road access, construction power, telephone, and potable water supplies available within one mile.
16. The costs for demolition, clearing and grubbing during site preparation will not exceed $500,000 or 2,300,000 cubic meters of earth.
17. Rock excavation below 50 meters from grade may be required, but special fill or compaction will not.
18. Soil is pervious with medium percolation qualities.
19. Water table is 5 meters below grade.
20. Extreme temperatures (+90ºF and -10ºF) will only occur 1% of the time and the site may be subject to tornadoes. The project will begin in a season when the weather is conducive to early construction work.
21. Sand and gravel suitable for nuclear-grade concrete will be available within 50 miles of the site.
22. Conventional solid waste disposal facilities will be available within 20 miles of the site and able to accept non-hazardous construction wastes.

2.4. Construction Assumptions

23. The service and other ancillary buildings are not designed in detail because of potentially different site-specific requirements and owner preferences. Most of these buildings will be constructed by a general construction, commercial-type sub-contractor.
24. Modules will all be assembled "out-of-hole" and the plant erected using a vertical open-top construction method.

2.5. Engineering and Procurement Assumptions

25. All plant design and engineering, with the exception of site-specific engineering, will be complete prior to owner commitment to build the plant. Site-specific engineering should be complete in time to support site preparation. Engineering should not hinder procurement and construction activities.
26. All deliveries will be made by truck or rail.
27. An automated Rebar Placement Machine will be obtained from Japan, installed, and fully operational prior to beginning construction on the Reactor Building and Reactor Building modules.

3. DETAILED SCHEDULE EVALUATION

A detailed evaluation was performed using the approach described in Section 1.4.2 on the following phases of the ESBWR schedule: Engineering, Procurement, Construction, Start-up and Commissioning, Training, and Licensing Inspections and ITAAC. The results of the detailed evaluation are provided in Tables B-2 through B-7 and summarized below.

3.1. Engineering

Scope

As the construction and modularization schedule (provided by GE in Appendix F of Reference 3.1) begins with the issuance of the COL, most engineering activities are assumed to be already completed. Accordingly, Conceptual and Preliminary Design activities for module and overall construction are not explicitly provided in this schedule and Detailed Design activities are limited to site-specific engineering.

The simulator schedule (Reference 3.2) allots time for the engineering design and manufacturing of the simulator computer, GE Test Program, and Main Control Room Panels. Although these activities are very high-level for the construction of the simulator, the scope is judged to be adequate and shows that the importance of the simulator to plant startup has been considered by GE.

Duration

The majority of the site-specific engineering takes place in the 18 months between the contract effective date (CED) and pouring the first structural concrete. Engineering that continues into the construction period (from month 19 onward) is completed before work is begun on the relevant system or building.

The simulator schedule (Reference 3.2) provides two years for design and manufacturing before the simulator is shipped to GENE Headquarters for testing.

Logic

Site-specific engineering of the major buildings and systems of the ESBWR occurs primarily in the months before physical work begins. While this logic is reasonable, engineering efforts should be extended into the schedule to account for the relatively untested construction practice of modularization.

3.2. Procurement

Scope

The schedule includes time for obtaining long-lead items, bulk items, and other parts specifically engineered for the ESBWR (i.e., pumps, etc.). Long-lead items related to the Reactor Building and Turbine Building are placed on the critical path and detailed to determine award, fabrication initiation, and delivery dates. Shop testing and transportation concerns are not explicitly detailed within the schedule. However, these items are discussed in the supporting literature and may be folded into the overall duration.

The procurement activities associated with modularization are discussed in detail in Section 3.2 of Reference 3.1 and are broadly included in the construction schedule for each building. Procuring modules within the schedule is in accordance with the open-top construction philosophy and “just in time” delivery.

The schedule does not explicitly address transportation issues and shop-testing and qualification. These items may be included in the overall fabrication and delivery scope, but that is not clear from the provided literature.

Duration

The duration of procurement for long-lead items is given extensive thought throughout the schedule as many of these items require several years to fabricate. Some of these durations coincide with or precede the CED. Many bulk items also have long procurement durations to illustrate the need for different quantities of equipment at different times. By distributing the delivery of items over the span of the project, storage space and other overhead costs may be minimized.

The durations assigned for the procurement of modules is vague, depending primarily upon the module fabricator subcontractor to provide schedule details that will match the larger goals and deadlines of the project.

Logic

Once the modules are delivered from the off-site subcontractor to the work site, additional time is provided for general assembly of modules and final installation at each elevation in each major building. This logic is generally considered to be reasonable, but will require structured project management practices to ensure that modules are assembled and placed correctly.

3.3. Construction

Construction activities in the ESBWR schedule are divided among site preparation, building construction and system completion/turnover activities.

Scope

The scope of site preparation activities includes time for the excavation and dewatering of the site, construction of storage areas, and means of transportation to the site. Expected activities, such as preparation of a laydown area, designation of equipment assembly areas, and construction of temporary security facilities, are not included.

The scope of building construction activities includes all elevations of the major buildings with modular and structural components. The major buildings considered are: Reactor Building, Auxiliary/Controls Building, Turbine Building, Radwaste Building, various Annex Facilities (such as Site Security Building, Training Center Building, and Services Building), Administration Building, and Water Intake Structures.

The scope of activities included in the completion and turnover of plant systems includes milestone activities for the completion of major tasks. These activities typically include the final construction of a system prior to large-scale, plant-wide testing. Some of the included systems are the switchyard, reactor systems, turbine generator systems, simulator systems, electrical systems, and water treatment systems. Note that, as this plant is a passive design, safety systems are not considered distinct from other operations systems.

Duration

The durations allotted for site preparation are all less than a year and are to take place in the time between the CED and pouring the first structural concrete. Following the completion of site preparation, work is begun on the reactor building and turbine building, as these buildings require the longest time to construct (34 and 33 months, respectively). Durations for the construction of each elevation within these buildings are also provided in stacked fashion so different disciplines may work on different elevations simultaneously. Construction on other buildings start soon after, as labor is available and have shorter durations overall.

Little information is available on the durations required to complete all internal systems and turn them over for commissioning.

Logic

In general, the logic for the construction of the ESBWR proceeds as expected for a large-scale, open-top project. Buildings and systems that require more effort are begun early in the schedule and more minor buildings and systems are constructed as labor becomes available. This logic is judged to be reasonable.

3.4. Start-up and Commissioning

Start-up and commissioning activities include system testing and qualification, fuel loading, and final commissioning. Table B-5 contains a more detailed evaluation and shows that the start-up and commissioning activities for the ESBWR are generally considered to be reasonable.

System testing and qualification activities are included on a high level for most systems. After construction of each building has finished, approximately 4-12 months are allowed for general "systems testing," without specifying which particular systems will be tested and how systems that overlap buildings are treated. However, information provided in the design book and through informal transmittals indicates that GE has extensively considered testing and will be mapping the testing out further as systems are finalized. Notable systems for which no testing time has been included are: electrical systems, water treatment systems, and auxiliary systems such as fire protection. All individual system testing is completed prior to LOOP / LOCA Testing.

Fuel loading and final commissioning are included in the final start-up phase of the construction schedule. GE has provided a separate schedule for this phase, which begins with fuel load and proceeds through 6 months of power ascension tests until final turnover / commercial operation. The tests are run at gradually increasing power levels to check the capabilities of the plant and ensure readiness for commercial operability.

3.5. Training

Both the construction and simulator schedules allot time for operator training. This training includes the assignment of personnel, preparation of training manuals, classroom training time and hands-on simulator training time. Operator training begins early in the construction process, and continues throughout to ensure that operators are trained and available when they are required for start-up testing and other activities. Large-scale testing such as the reactor pre-operation tests and control rod drive tests are not performed until the operators have had at least 6 months to train on the simulator. The durations and logic of training activities should be sufficient to support all plant operability requirements.

3.6. Post-COL Licensing and ITAAC

Although GE has recognized the need for ITAAC activities in the construction assumptions and other communications, the time for inspections and reviews has not been explicitly included in the schedule. These activities may be proceeding in parallel with construction tasks and included in the 17,500 activity fully integrated schedule. Per Reference 3.7, GE anticipates that 498 individual inspections, tests, or analyses will be required for ITAAC.

4. Impact of Modularization

The structural modules planned for adaptation and use in the GE ESBWR have been used successfully on the ABWR to significantly reduce construction time. The modularization planned for the ESBWR is made possible by the major simplification of the systems and structures in the new plant design. Modules will be lowered into position once the floor elevation on which they sit is complete. GE plans three modularization methods for the ESBWR:

- On-site assembly and modularization of equipment,
- Equipment manufacturers providing components that are complete and assembled more than usual, or
- All equipment provided to a central offsite facility for assembly and installation into modules.

The modules may be massive and require special transportation methods.

There are fifteen module types:

- Reactor building (RB) and auxiliary fuel building (FB) precast stair tower/elevator shaft modules.
- RB, FB, and control building (CB) structural steel/metal deck modules.
- RB, FB, and CB prefabricated rebar mat modules.
- RB upper base mat rebar/embedment module.
- RB bottom Reinforced Concrete Containment Vessel (RCCV) liner module.
- RB RCCV wall rebar modules.
- RB RPV pedestal module.
- RB RCCV diaphragm floor liner module.
- RB upper RCCV wall liner module.
- RB drywell equipment and piping support structure (DEPSS).
- RB RCCV top slab liner module.
- RB and FB pools liner modules.
- RB and FB roof truss structural steel modules.
- RB, FB, and CB general area rebar modules.
- RB, FB, and CB forms and supports modules.

The DEPSS consists of the RPV shield wall, the DEPSS structural steel, and integrated piping duct, and electrical components. It is the heaviest and most complex of the modules and provides the most schedule benefit if implemented.

The majority of the module types are civil works. GE acknowledges there may be advantages to development of modules for mechanical and electrical components. It should be noted that GE's ABWR design includes equipment modules in addition to civil modules. GE plans to maximize modularization benefits during the detailed design phase.

In GE's modularization plan for the ESBWR, the major benefits to shorten the schedule will come in the areas of: reactor building structures, the reactor vessel and connected piping and valves, equipment like control rod drives in the reactor building, the Reactor Water Cleanup System, and the Shutdown Cooling System. The modularization of the DEPSS will permit the RPV shield wall assembly to be constructed concurrent with other RCCV work, saving significant critical path time. Additional smaller benefits are anticipated in the fuel and control buildings. GE anticipates reduced or no benefit from modularization of activities that are not on the critical path.

5. CRITICAL PATH EVALUATION

The GE ABWR critical path construction and commissioning schedule spans 66 months and includes 118 activities. The critical path includes activities related to the procurement and installation of the reactor pressure vessel (RPV), site preparation and excavation, reactor building construction, turbine building construction, control building construction, transformer installation, pre-fuel load testing, and post-fuel load testing. Per Reference 3.6, since, unlike in the ABWR, the control room for the ESBWR is a separate structure, control building construction will be removed from the critical path.

Procurement Phase

Initial critical path activities include procurements related to the reactor systems. The reservation for RPV material must be placed a full year prior to the owner committing to the construction of the plant. The award process for the RPV, RPV Pedestal, and RCCV Liner Plate must occur in the last three months of that process. The fabrication of the RPV will begin immediately after the owner contract is effective and last 33 months. The fabrication of the RPV pedestal and RCCV Liner will begin five to six months after the contract award and last 12 months and 9 months, respectively. These durations are considered appropriate for procuring the RPV materials in time for Reactor Building Construction. Timeliness of procurement activities will be crucial to the success of the project. Contacts with vendors should be made early and relationships well-established prior to initiating the 1st-of-a-kind plant. See Section 4 of this appendix and Section 2.1.3 in the body of this report for a discussion of potential impacts to the procurement critical path as a result of modularization.

Site Preparation Phase

Following the initiation of the procurement activities, the site preparation phase begins. In the six months between contract award and the start of work, on-site utilities and facilities are installed up to the boundary of the site. Additionally, the site engineers will complete the pertinent site drawings. Site preparation activities begin with the cut and fill of site soil and running roads, rails, and construction power through the site (five months). Once the site is fully accessible, the dewatering system is installed and the site is excavated (seven months) in parallel with the assembly of the basemat (five months) and lower shell modules (seven months). The 12 months allowed for site preparation on the critical path is considered reasonable for the amount of work to be completed. As the ESBWR will have a smaller basemat than the ABWR, it is also possible that time will be saved during excavation due to the reduced scope of work.

Reactor Building Construction Phase

The next set of activities on the critical path is primarily related to the construction of the reactor building and turbine building structures. The nine elevation levels of the reactor building are constructed by first building the walls, setting the equipment modules roughly in place, and then building the floor of the next story. As the structural crew continues to build upward, the mechanical and electrical (M&E) crews can complete the systems installation within the modules on the levels below. M&E completion does not become critical path until the structural work is completed. Following the completion of all M&E systems, the reactor systems are tested in preparation for startup. The installation of the RPV and completing the building to grade are the two critical path milestones noted on the critical path schedule. Forty-two (42) critical path months are required to construct and test the reactor building.

Turbine Building Construction Phase

The construction of the turbine building structure is considered to be near-critical path and proceeds in much the same way that the reactor building was constructed. For the seven elevation levels of the turbine building, walls are built, the equipment modules are set roughly in place, and then the floor of the next elevation is built. M&E crews work in parallel with the structural crews and finish their work approximately 8 months after the structure is complete. After approximately 75% of the M&E work is finished, turbine system testing begins and continues on a near-critical path until startup. Completing the building to grade and setting the moisture separators are noted as critical milestone activities. Following the completion of the structural portion of the turbine building, installing the main, unit auxiliary, and reserve transformers is added to this near-critical path. These transformers are then tested with the auxiliary electric system prior to energizing the auxiliary electric system. Thirty-four (34) near-critical path months are required to construct the turbine building.

System Commissioning Phase

As construction is finished, the following systems are sequentially brought on-line along the critical path:

- Auxiliary Electric
- Multiplex
- Instrument Air
- Demineralized Water
- Equipment Cooling
- Normal Chilled Water
- Main Steam
- Condensate
- Feedwater
- Reactor Water Cleanup
- Residual Heat Removal
- High Pressure Core Flooder

- Reactor Core Isolation Cooling
- Suppression Pool Cleanup
- Fuel Pool Cooling & Cleanup Reactor Recirculation
- Standby Liquid Control

Note that these are all systems required for the ABWR and it is expected that many may be eliminated for the ESBWR design. This will significantly reduce the duration of critical path required for system startup. Prior to operating the NSSS systems, all systems will be flushed and cleaned. Eleven (11) months in the schedule are provided for starting up these systems.

System Testing and Start-up Phase

After the systems are determined to be operational, a series of tests are performed prior to fuel load. These tests include:

- Reactor Pre-Operational Tests
- RPV Operation Hydrodynamics Test
- RPV Flow Vibration Test
- Control Rod Drive Tests
- Containment Pressure and Leak Tests
- LOOP/LOCA Test.

Six months are allotted for these tests. After the conclusion of these tests, it is assumed that the NRC will have 100% acceptance for all ITAACs required for fuel load. Refer to Section 2.1.4 of the body of this report for a discussion of potential impacts on critical path from ITAAC.

One month on the critical path is allotted for fuel load. After this point, the critical path proceeds through open vessel pre-critical testing to nuclear heatup testing at 5% power which begins power ascension testing. Five months are allotted for these tests and commercial operation should be achieved when they are complete.

Near Critical Path

GE states in Section 2.2.2 of Reference 3.1 that there are several other near-critical paths that proceed through procurement and civil construction. However, the level of design detail and project status at the time this ABWR schedule was published did not allow for further schedule reduction. These near-critical paths will need to be further researched once detailed information is available for the ESBWR.

6. FIRST-VERSUS-NTH-OF-A-KIND

All schedule assessments for the GE ESBWR are based off the First-of-a-Kind (FOAK) Construction and Modularization Plan for the GE ABWR provided in Appendix F of Reference 3.1, since a detailed schedule study has not yet been performed for the ESBWR. From the GE ABWR schedule, the overall duration from first structural concrete to commercial operation is expected to be the same for FOAK and NOAK plants. Preliminary studies of the SBWR and

ESBWR, however, illustrate potential schedule differences between FOAK and NOAK schedules for ESBWR units.

In their ABWR schedule, GE specifies 60 months from the beginning of site preparation to commercial operation (six months are added to the critical path schedule prior to official site preparation for pre-commitment site activities and site specific-engineering). This schedule includes 12 months for site preparation, 42 months for plant construction to fuel load, and 6 months for power ascension testing prior to commercial operation. This results in a 48-month duration for FOAK construction from “first structural concrete” to “commercial operation.” Per Reference 3.6, GE estimates that the next ABWR (NOAK) will require 48 months from “first structural concrete” to “commercial operation.” Since the duration for site preparation is not expected to change radically for NOAK units, a 60-month overall schedule therefore seems reasonable for NOAK plants.

However, GE provided information regarding the anticipated schedule for the SBWR, which illustrates potential schedule reductions for NOAK units. The construction of the ESBWR is expected to more closely mimic the construction of the SBWR than the ABWR as the designs are closer together on the evolutionary path. A 1992 study by Bechtel of the SBWR showed 39 months[15] from first structural concrete to fuel load for FOAK plants. For NOAK plants, the study showed 30 months from first structural concrete to fuel load. After considering the smaller basemat, slightly larger containment structures, and the reduced overall reactor building size of the ESBWR, the study concluded that the schedule for NOAK ESBWR could be reduced to approximately 28 months from first structural concrete to fuel load (Reference 3.6). This results in an approximate 9 – 11 month schedule reduction for NOAK ESBWR units. A detailed study of the project plant construction schedule for the ESBWR has not yet been performed; therefore, these conclusions are to be considered as only preliminary.

GE anticipates that the NOAK schedule reductions will result primarily from stream-lining the construction process and reduced time for engineering, procurement, and licensing activities. As modularization is still a relatively new construction concept, GE recognizes that all the advantages of modularization may not be realized in a FOAK plant. As additional plants are constructed, the extent of the modularization used may be increased or reduced depending on lessons learned during construction of the first plant (Section 3.1.2, Reference 3.1). Schedule durations are expected to change to reflect these lessons. GE also notes that investments made in unique modularizing tools for a FOAK plant will provide both cost and schedule benefits in NOAK plants. These tools may include cranes, automatic rebar placement machines, and assembly jigs (Section 3.2.2.1, Reference 3.1). GE has extensive plans for analyzing the FOAK effort to make improvements in subsequent NOAK plants. Refer to Section 2.1.3 of this report and Section 4 of this appendix for a discussion of how modularization may impact the schedule. Engineering and procurement activities in advance of and in parallel with site preparation activities are expected to take additional time for a FOAK plant. NRC oversight and approvals

[15] Using this SBWR study as their reference, Dominion cites these 39 months as the duration from first structural concrete to fuel load. MPR cites 42 months for this duration based on the ABWR study (Reference 3.1). This is consistent with the philosophy of MPR-2627 and guidance from GE to use ABWR information as a source for postulated ESBWR schedule data. Dominion’s study did not rely as significantly on the ABWR data for the ESBWR.

prior to fuel load and after fuel load may also add to the total schedule duration for a FOAK plant. For additional discussion regarding potential regulatory and licensing impacts, refer to Section 2.1.4.

7. SUMMARY OF VENDOR RISK ASSESSMENT BY VENDOR

GE performed a schedule risk analysis for the ABWR schedule. This analysis is provided in Appendix L of Reference 3.1. As detailed plant construction schedules have not yet been formulated for the ESBWR, this information is considered the best available to assess the risks of GE construction schedules. The ABWR analysis considers construction assumptions, critical path and near-critical path activities, schedule logic, random uncertainty, deterministic uncertainty, and global uncertainty to determine the areas of the greatest potential risk and how risk reduction strategies may be incorporated into the project. This analysis only investigated FOAK schedules. Additional studies would be required to understand the risks of NOAK plants.

Rather than assessing the uncertainty of individual schedule activities, GE analyzed the construction assumptions for potential impacts on the overall schedule duration. This would allow the project managers to see what the most influential assumptions are and focus their energies accordingly. Construction assumptions, listed in Section 2.4 of this appendix, were categorized into the following concepts:

- Engineering Complete Prior to Owner Commitment
- Quality and Inspections
- Work Schedule Impacts
- Construction Labor Efficiency
- Site and Subgrade Conditions
- Dewatering Requirements
- Equipment and Material Delivery
- Modularization Benefits
- Weather Delays
- Electronic Communications and Information Management
- Project Organization Effectiveness

The impact of each of these assumptions was examined to determine the best possible effect (most likely to shorten the schedule) and worst possible effect (most likely to lengthen the schedule). Potential durations in both directions were estimated and a nominal sensitivity study was performed to determine the impact of each assumption. The five critical assumptions that were found to have the potential for the most impact on the schedule were: project organization effectiveness, modularization benefits, construction labor efficiency, work schedule, and engineering completeness. Accordingly, these are the topics that should be researched and given primary importance in preparation for the construction phase. The EPC contractor can actively make decisions regarding the work schedule (4x10 days vs. 5x10 days, etc.) and the completeness of engineering prior to owner commitment (internal reviews and interfaces with the NRC) that will give the project the highest probability for success within the predicted schedule. Modularization, project management, and construction management systems are prone to more uncertainty, but early attention paid to these topics should help minimize the risk of unnecessary duration.

To understand the consequences of different schedule scenarios and the tangible effects of these assumptions, Monte Carlo simulations using the Critical Path Method (CPM) were used by GE to calculate duration probabilities. Five scenarios were explored:

1) Base Case – No action taken to mitigate the five critical assumptions.

2) Case A – Base Case with 40% of the engineering complete prior to owner commitment.

3) Case B – Base Case with a 5x10 work schedule.

4) Case C – Organizational Management is as effective as possible (experienced crew, strong EPC management team, high level of teamwork).

5) Case D – Modularization and construction labor efficiency are most effective (adequate supply of labor, productivity is high, increased efficiency of current modules, additional module design is performed).

Based on the five scenarios, the confidence in a 48-month schedule from first structural concrete to commercial operation is calculated in Table B-1.

Table B-1. GE ESBWR Schedule Confidence Based on Case Study Scenarios

Scenario	Confidence in 48-month Construction Schedule
Case D	78%
Case C	72%
Base Case	31%
Case A	4%
Case B	0%

Based on this study, the additional engineering effort performed for the ESBWR (based on work already performed for the ABWR and SBWR), and the information provided in the comparative study by Bechtel (Reference 3.6), it is probable that the ESBWR will be constructed in less than 48 months.

Table B-2. GE ESBWR Schedule Evaluation
Engineering Phase

Activity	Scope	Duration	Logic
A. Conceptual and Preliminary Design[a]			
Discipline Specific	The Project Summary Schedule (PSS) includes very little information regarding conceptual and preliminary design work, as this is assumed to be completed prior to the owner committing to construct. This information may be folded into the durations for the Detailed Engineering.	N/A	N/A
Simulator	The design of the simulator computer, GE test program, and simulator main control room panels are given as line items in the preliminary simulator design included in Reference 3.2.	As the design phases are not split into preliminary vs. detailed, and the manufacturing time is included in the total provided, it is considered reasonable to dedicate ¼ of the total time to preliminary and conceptual engineering. Therefore, the durations for preliminary engineering is: - Simulator Computer = 6 mo - GE Test Program = 1.5 mo - Main Control Room Panels = 4 mo Little additional information is available regarding the durations required to design a simulator, however, based on past engineering experience, these durations should be sufficient to complete the conceptual design of the simulator.	The preliminary and conceptual design of the three simulator components proceed in parallel, presumably to be completed prior to manufacturing. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
B. Detailed Design[a]			
Discipline Specific	The engineering activities in the schedule are organized according to discipline. Detailed design activities are included in the schedule for the disciplines of; Structural, Mechanical, Chemical, and Electrical. Examples of detailed design activities include: manual completion, P&ID drawings, one-line drawings, control logic design, site preparation drawings, underground/temporary facility drawings, power block detail, and yard structures detail. The schedule also includes milestone activities for the completion of engineering related to obtaining the COL and equipment procurements. This scope is judged to be reasonable and complete.	The amount of detailed design work varies depending on the discipline. The duration for each discipline is approximately: - Structural = 20 mo - Mechanical = 24 mo - Chemical = 15 mo - Electrical = 27 mo All site-specific engineering is completed in the 27 months after CED. Engineering work should be able to be completed in this duration by supplementing the staff and hiring additional contractors, as necessary. Therefore, this duration is judged to be reasonable.	Only the preparation of site preparation drawings is critical path for the overall schedule. In general, other activities proceed in parallel, completing engineering activities well before construction of each system is completed. This logic is judged to be reasonable.
Simulator	The design of the simulator computer, GE test program, and simulator main control room panels are given as line items in the preliminary simulator schedule included in Reference 3.2.	As the design phases are not split into preliminary and detailed engineering and the manufacturing time is included, it is considered reasonable to dedicate 1/3 of the total time to detailed design engineering. - Simulator Computer = 8 mo - GE Test Program = 2 mo - Main Control Room Panels = 5.5 mo Little additional information is available regarding the durations required to design a simulator, however, based on past engineering experience, these durations should be sufficient to complete the conceptual design of the simulator.	The detailed design of the simulator proceeds in parallel among the three tasks, presumably to be completed prior to manufacturing. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Modules	Engineering activities related to modules are not included in the PSS. A detailed discussion of potential modules is included in Section 3 of Reference 3.1 and much of this work is assumed to be completed prior to the construction phase. Especially for the first plant of this type, more scope and engineering time should be considered for modules in the construction schedule. The level of detail needed for further evaluation was not provided. Detailed module engineering activities should be developed as a part of subsequent scheduling efforts.	N/A	N/A

References and Notes:

a. Unless otherwise noted, schedule information is from Appendix F of Reference 3.1.

Table B-3. GE ESBWR Schedule Evaluation
Procurement Phase

Activity	Scope	Duration	Logic
A. Component Procurement[a]			
Long-Lead Items	The equipment and material procurement items in the PSS are divided by discipline into various packages: Structural, Mechanical, Electrical, Control, Chemical, Fuel, and Lubricant. Within these packages the following items are specified as long-lead: Reactor Pressure Vessel (RPV) Pedestal, Reinforced Concrete Containment Vessel (RCCV), RPV, Batteries and Chargers, Feedwater Pump (FWP) motor and drive sets, Main Control Panels, Emergency Generator, Turbine / Generator. This scope is judged to be complete and consistent with the scope of long-lead items required for other plants. Components for modules may also be required early to meet schedule needs. This should be further evaluated as module engineering is developed.	The duration assigned for fabrication of some of the long-lead major equipment is approximately: - RPV (including reservation) = 47 mo - Main Control Panels = 24 mo - Turbine / Generator = 33 mo Bid evaluation and award periods are not included in the durations above (typically an additional 2-3 months). Section 4.1 of Reference 3.1 states that there are several pieces of major construction equipment that will require some lead time. This equipment includes: Automated Rebar Placement Machine, Module Transporter, and RCCV Area Lifting Trusses, which will require structural design. These durations are judged to be sufficient based on comparison with other plants.	Some bid evaluations are performed prior to the owner commit to construct date. However, no items are fabricated until after the contract effective date. This logic is judged to be reasonable. In general, procurement activities precede or are in parallel with module fabrication and construction activities. This logic is judged to be reasonable. The overall philosophy of the project is to embrace a “Just In Time” (JIT) delivery system to reduce storage costs, yet not hinder construction progress. This logic has been successfully implemented on other projects and is judged to be reasonable.

Activity	Scope	Duration	Logic
Bulk Materials	Bulk order materials including valves, pipe, piping supports, structural steel, ducts, and conduits are included in the schedule to be delivered in parallel with construction activities. This scope is judged to be reasonable.	The duration assigned for the manufacturing and delivery of bulk order materials is approximately: - Standard Valves = 21 mo - Pipe/Fittings = 21 mo - Pipe Supports = 20 mo - Structural Steel = 20 mo - Ducts and Conduits = 24 mo The schedule does not include bid evaluation and award periods for all bulk materials (typically 3-4 months). It is likely that these materials will be delivered in batches over the entire delivery period to avoid storing large quantities of materials before they are needed. These durations are judged to be sufficient based on comparison with other plants.	Bid evaluations and awards are performed after the owner commit to construct date. However, the EPC contractor may develop a potential list of vendors prior to this date to facilitate the award process. This logic is judged to be reasonable. The bulk order materials are manufactured before they are transported. This logic is judged to be reasonable.
Shop-Testing and Qualification	Time is allotted in the schedule to set up construction testing facilities, however, activities related to the testing and qualification of major equipment are not explicitly included in the schedule. Delivery durations should be examined to determine whether sufficient time is allowed between the beginning of fabrication and the delivery date to permit testing and qualification.	Three (3) months are allotted for mobilizing the construction testing facility. Other durations are not provided.	N/A
Transportation	Activities associated with the transport of major equipment and bulk orders are not explicitly included in the scope of the schedule.	N/A	N/A

Activity	Scope	Duration	Logic
B. Module Fabrication and Assembly[a]			
Shop Fabrication and Assembly	Section 3.2.2.7 of Reference 3.1 discusses the requirements for the off-site shop of the modularization sub-contractor. Awarding module assembly activities to an off-site shop is mentioned in the schedule under procurement activities. Off-site module assembly is included for each major building/system under the construction schedule for each. This scope is judged to be complete, but at a low level of detail.	The duration assigned for the award of the contract to the off-site module assembly shop is 4 months. This duration is judged to be reasonable based on other contract awards within the schedule. The amount of time allowed for the off-site fabrication of modules on some major buildings/systems is as follows: - Reactor Building = 29 mo - Turbine Building = 21 mo - Control Building = 18 mo - Radwaste Building = 4 mo The total number of modules was not provided, therefore, no evaluation of the appropriateness of these durations is possible. However, the durations are similar to those achieved on other construction projects.	The award of the contract for the off-site module assembly shop occurs before most construction activities. This logic is judged to be reasonable. Off-site module fabrication activities occur in parallel with the construction of each building/system to be delivered in "Just-In-Time" fashion. This logic is judged to be reasonable.
Shop-Testing and Qualification	Activities related to the testing and qualification of modules in the fabrication shops are not explicitly included in the schedule.	N/A	N/A
Transportation	Activities associated with the transport of modules are not explicitly included in the schedule. However, based on discussion in Section 3.2.2.7 of Reference 3.1, the vendor understands that transportation is an issue. More detail needs to be included on transportation in the schedule to understand how modules will arrive on-site.	N/A	N/A
On-site Fabrication and Assembly	Activities associated with the assembly of modules on-site are included in the schedule for each major building/system and the elevations within that building/system. This scope is judged to be reasonable and complete.	The duration assigned for the on-site assembly of the modules ranges from 2 to 18 months. Shorter durations are broken out for the assembly of modules at specific elevations. Based on a comparison with other plants, these durations are judged to be reasonable.	The assembly of modules on-site is performed consistently with an open-top construction method. Modules at lower elevations will be assembled first, followed by higher level elevations. This logic is judged to be reasonable.

References and Notes:

a. Unless otherwise noted, schedule information is from Appendix F of Reference 3.1.

Table B-4. GE ESBWR Schedule Evaluation
Construction Phase

Activity	Scope	Duration	Logic
A. Site Preparation[a]			
Soil Preparation	The schedule includes soil preparation activities such as cut and fill time, drainage installation, and dewatering system installation. This scope is judged to be reasonable and complete.	The duration assigned for soil preparation is approximately as follows: - Cut & Fill = 4 mo - Drainage Installation= 7 mo - Dewatering System = 3 mo - Excavation = 5 mo These durations are judged to be sufficient for site preparation based on industry experience with other construction projects.	Soil preparation activities precede the installation of any utilities or major equipment. These activities follow initial site-specific engineering activities and the work necessary to support on-site construction (i.e., bringing utilities up to the site boundary and obtaining all necessary local permits). This logic is judged to be reasonable.
Laydown Area Preparation	Although a laydown area is discussed in Section 4.1.1 of Reference 3.1, activities related to the preparation of the laydown area are not explicitly included in the schedule.	N/A	N/A
Storage Area Construction	The schedule includes time for the construction of a temporary construction warehouse, a main warehouse, and a controlled warehouse. This scope is judged to be appropriate.	The duration assigned for storage area construction is approximately as follows: - Temporary Warehouse = 4 mo - Main Warehouse = 6 mo - Controlled Warehouse = 7 mo Based on the increasing complexity of each of these structures, these durations are judged to be sufficient for storage area preparation.	The temporary warehouse is constructed as soon as allowed by the preparation of the soil. The main warehouse and controlled warehouse (permanent structures) are constructed early in the overall schedule to maximize the overall storage space. This logic is judged to be reasonable.
Equipment Assembly Area	Activities related to the preparation of the equipment assembly area are not explicitly included in the schedule, but time may be provided for in general site preparation activities.	N/A	N/A

Activity	Scope	Duration	Logic
Road and Rail Construction	Activities related to the construction of roads and railroad lines are included in the schedule. Road construction may be completed during site finalization. This scope is judged to be appropriate.	The durations assigned for road preparation are approximately as follows: - Construction Roads = 7 mo - Railroad Construction= 4 mo These durations are judged to be sufficient for transportation preparation based on comparison with other construction schedules.	The construction of transportation thruways occurs before any of the off-site modules or other large equipment are to arrive on-site. This logic is judged to be reasonable.
Security Construction	Activities related to the construction of a permanent site security facility are included in the schedule, although activities related to the construction of a temporary site security facility are not. However, temporary guard houses are shown on the ESBWR plot plan.[b] The schedule should include time to arrange for a site security facility for the construction period.	The duration assigned for the construction of site security facilities is 5 mos. for building construction and 5 mos. for interior construction. This duration is judged to be reasonable based on prior building construction experience.	The construction of the site security facility occurs well after construction has begun on most of the major buildings and systems. This is reasonable to meet security requirements for operation, but does not meet the needs for security during construction.
Temporary Office Space and Services	Activities in the schedule related to temporary office space and services include: a field management office, construction power and communications, sanitary treatment systems, medical and testing facilities, and a concrete batch plant. This scope is judged to be sufficient for temporary facilities and services.	The durations assigned for the construction of some of the primary temporary facilities and service are approximately: - Field Management Office = 5 mo - Communications = 6 mo - Medical Facility = 2 mo These durations are judged to be reasonable for the construction of temporary facilities and services based on prior building construction experience. Some of the shorter durations may be attributable to the use of temporary structures like trailers.	The construction of these facilities is completed before the beginning of the construction of the reactor building and other major systems. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
B. Building Construction[a]			
Reactor Building (Containment Vessel, Shield Building)	Activities in the schedule related to the construction of the Reactor Building begin with the placement of the basemat and construction of the Reinforced Concrete Containment Vessel (RCCV). Activities continue with installing equipment modules on successively higher elevations in parallel up to grade level. After grade level, further equipment modules are installed through final installation of the roof. Nine elevations are installed roughly corresponding to those shown on the Reactor Building Drawings (Reference 3.4). This scope is judged to be sufficient for the level of detail provided in this schedule; however, more detailed schedules and a listing of the modules need to be assembled prior to construction.	The entire construction of the Reactor Building is estimated to take approximately 34 months from the installation of the basemat through the completion of the Mechanical and Electrical (M&E) systems construction. The durations allowed for module assembly on-site for the reactor modules range from approximately 5 to 11 months. The durations assigned for the placement of the Reactor Modules (Rough Equipment Set plus Surface Coating plus M&E Construction) are approximately as follows: - Elevation -8200 = 17 mo - Elevation -1700 = 17 mo - Elevation 4800 = 17 mo - Elevation 12300 = 15 mo - Elevation 18100 = 14 mo - Elevation 23500 = 9 mo - Elevation 27200 = 11 mo - Elevation 31700 = 7 mo - Elevation 38200 = 4 mo In general, less time is required to install the modules at higher elevation than at lower elevations. This is logical, as the heavier and more complex equipment is typically located lower in the reactor building. The exception at 27200 is due to the steam dryer separator. These durations are judged to be reasonable based on previously achieved durations for nuclear plant construction projects in the U.S., considering reductions for modularization.	The reactor building is constructed using an open-top method, which constructs lower elevation structures first and gradually builds up. The RCCV is constructed first, providing the framework for the installation of equipment modules. The modules are installed from the bottom up, placing equipment as the structure is sound enough to support it. The schedule accounts for the availability of the overhead crane. This logic is judged to be reasonable.
Auxiliary Building	The services typically provided by an auxiliary building are included in the reactor building structure. A separate auxiliary building will not be constructed.	N/A	N/A

Activity	Scope	Duration	Logic
Turbine Building	Activities in the schedule related to the construction of the Turbine Building begin with the placement of the basemat and construct modules successively upward. Three elevation levels of modules are constructed with the levels roughly corresponding to those shown on the Turbine Building Drawings (Reference 3.5). However, these drawings do not detail what the individual modules are and a listing/more detailed schedule will be required prior to construction. This scope is judged to be sufficient for the level of detail provided in this schedule. The Turbine Generator Systems are set up in two phases. The first sets the turbine generator pedestal and the condensers; the second erects the turbine generator. Additional Turbine Generator modules are set according to open-top construction principles. This scope is judged to be reasonable.	The entire construction of the Turbine Building is estimated to take approximately 33 months from the installation of the basemat through the completion of the Mechanical and Electrical (M&E) systems construction. Including the erection of the turbine generator adds 3 months to the duration. This duration is judged to be reasonable based on previous plant construction projects. The durations assigned for the placement of the Turbine Modules (Rough Equipment Set plus M&E Construction) are approximately as follows: - Elevation 5300 = 14 mo - Elevation 12300 = 13 mo - Elevation 20300 = 18 mo Approximately 9 months are given for construction of the pedestal area. Thirteen months are given for the erection of the turbine generator. The durations are judged to be reasonable based on the durations achieved in previous nuclear plant construction projects in the U.S., considering reductions for modularization.	The Turbine Building is constructed using an open-top method, which constructs lower elevation structures first and gradually builds up. The schedule accounts for the availability of the turbine crane. This logic is judged to be reasonable and well thought-out.

Activity	Scope	Duration	Logic
Radwaste Building	Activities in the schedule related to the construction of the Radwaste Building begin with the placement of the basemat and construct modules successively upward. Radwaste Modules are put into place starting from lower levels and building upward. Seven elevation levels of modules are to be constructed. This scope is judged to be sufficient for the level of detail provided in this schedule; however, more detailed schedules and a list of modules will need to be provided prior to final construction.	The entire construction of the Radwaste Building is estimated to take approximately 21 months from the installation of the basemat through the completion of the Mechanical and Electrical (M&E) systems construction. The duration allowed for module assembly on-site is 13 months. The durations assigned for the placement of the Reactor Modules (Rough Equipment Set plus Surface Coating plus M&E Construction) are approximately as follows: - Elevation -3700 = 7 mo - Elevation 2300 = 7 mo - Elevation 8300 = 8 mo - Elevation 12300 = 9 mo - Elevation 15100 = 7 mo - Elevation 18300 = 7 mo - Elevation 24300 = 5 mo (Note: no time is provided for surface coating for Elevation 24300) These durations are judged to be reasonable based on previous nuclear plant construction experience.	The Radwaste Building is constructed using an open-top method, which constructs lower elevation structures first and gradually builds up. The schedule accounts for the availability of the turbine crane. This logic is judged to be reasonable and well thought-out.
Diesel Generator Building	No Safety-Related Diesel Generators will be used in the ESBWR design. Two non-safety Diesel Generators have been preliminarily planned for and are located in a separate electrical building. Additional detail on these buildings has not been provided.	N/A	N/A

Activity	Scope	Duration	Logic
Annex Building	In the schedule, the Site Security Building, Training Center Building, and Services Building are all considered part of the overall Annex Building structure. Activities in the schedule for each of these buildings include building construction, interior construction, and building occupancy. This scope is judged to be reasonable.	The durations assigned for the construction of the Site Security, Training Center, and Services Buildings are approximately (building duration/interior duration): - Site Security Building = 5 mo / 5 mo - Training Center Building = 4 mo / 5 mo - Services Building = 12 mo / 6 mo Based on previous construction experience, these durations are judged to be reasonable for the construction of annex buildings.	The Training Center is built early in the schedule to facilitate the training of operators. The simulator equipment is installed in two months following the completion of the interior construction. The construction of the training center with simulator is completed. This logic is judged to be reasonable. As the Services building and permanent Site Security building are not as critical to the overall construction schedule, these items are performed later when sufficient labor is available. This logic is judged to be reasonable.
Main Control Building	Activities in the schedule related to the construction of the Control Building begin with the placement of the basemat and construct modules successively upward. Fuel loading and related functions are constructed along with the Reactor Building. Main Control Room Modules are put into place starting from lower levels and building upward. Seven elevation levels of modules are to be constructed. This scope is judged to be sufficient for the level of detail provided in this schedule; however, more detailed schedules and a list of modules will be required prior to final construction.	The entire construction of the Main Control Building is estimated to take approximately 27 months from the installation of the basemat through the completion of the Mechanical and Electrical (M&E) systems construction. The durations allowed for module assembly on-site for the reactor modules at each elevation range from 3 to 4 months. The durations assigned for the placement of the Main Control Room Modules (Rough Equipment Set plus Surface Coating plus M&E Construction) are approximately as follows: - Elevation -8200 = 13 mo - Elevation -2150 = 11 mo - Elevation 2900 = 10 mo - Elevation 7600 = 12 mo - Elevation 12300 = 7 mo - Elevation 17150 = 10 mo - Elevation 22200 = 1 mo (Note: no time is provided for rough equipment set for Elevation 22200) These durations are judged to be reasonable based on previous nuclear power plant construction experience.	The Main Control Building is constructed using an open-top method, which constructs lower elevation structures first and gradually builds up. This logic is judged to be reasonable and appears well thought-out.

Activity	Scope	Duration	Logic
Administration Building	Activities in the schedule related to the construction of the Administration Building include building construction, interior construction, and building occupancy. This scope is judged to be reasonable and complete.	The duration of the construction of the Administration Building is approximately 9 months for building construction and 8 months for interior construction. These durations are judged to be reasonable based on previous construction experience.	The Administration Building is built at a reasonable time in the schedule when construction labor should be available. As this building may require a large amount of detail work (painting, windows, drywall, etc.), sufficient time needs to be allowed to prepare the building for occupancy. The time and sequencing of the construction of the Administration Building is judged to be reasonable.
Circulating Water Building	Two water intake structures are scheduled to be built: The safety intake structure, which supplies service water to the reactor building and the non-safety intake structure, which supplies the circulating water. The non-safety intake structure is built in two phases: building construction and M&E construction. A cooling tower is built in parallel with the two intake structures. This scope is judged to be reasonable.	The non-safety intake structure has a construction duration of 4 months, split into two 2 month sections approximately 9 months apart. The M&E construction of the non-safety intake structure is given approximately another 3 months to complete. The construction of the cooling tower allows 2.5 months for circulation water piping installation; 13 months to install the basin, shell, and fill; and another 3 months to complete the M&E construction. These durations are judged to be reasonable.	The labor used to construct the circulating water structures seems to be divided between the non-safety intake structure and the cooling water tower. Work stops on the intake structure to make progress on the cooling tower, and then both structures are completed simultaneously. It is not obvious from the schedule whether this logic is solely attributable to labor, it may also be influenced by the availability of materials. Regardless, the logic is judged to be reasonable to allow for the completion of the circulating water structures before they are required for systems testing.
Transformers and Switchyard	Activities in the schedule related to the construction of transformers and the switchyard include installing main, unit auxiliary, reserve, and other auxiliary transformers; installing foundations; and constructing supporting structures. This scope is judged to be reasonable.	All transformers will be installed over a 3-month period. The switchyard and overhead lines will be completed in approximately 8 months with an additional 4 months for testing of the system. This duration is judged to be reasonable based on previous construction experience.	The installation of the transformers and switchyard occurs just prior to startup testing, but after most of the construction work is completed on the major buildings. This logic is judged to be reasonable
C. System Completion and Turnover[a]			
Transformers and Switchyard	Activities in the schedule related to the completion and turnover of the transformers and switchyard are not included in this schedule.	N/A	N/A

Activity	Scope	Duration	Logic
Reactor Systems	This scope includes completion of the safety intake system for reactor building service water, and the completion of the chilled water, main steam, feedwater, and other reactor systems. These systems are included in the schedule by their date of operation with little detail about the activities leading up to their completion. The scope of systems is judged to be reasonable, but limited in its level of detail. Information should be provided on other systems such as refueling and fuel transfer.	No durations are specified for the completion of these systems, only milestone dates. The systems are brought online approximately every 1 to 2 weeks after the M&E engineering is complete within the reactor building. Based on other plant schedules, this is judged to be reasonable.	The reactor systems are gradually brought on-line with time in between to troubleshoot any issues. This logic is judged to be reasonable.
Safety Systems	Safety systems are included in the overall design and construction of the Reactor Building and Reactor Building Modules. Safety systems are not differentiated within these buildings for completion and turnover.	N/A	N/A
Turbine Generator Systems	Activities related to the completion and turnover of the turbine generator systems include the turbine generator lube oil flush and setting the turbine on the turning gear. The scope also includes completion of the main steam and condensate systems. These systems are included in the schedule by their date of operation with little detail about activities leading up to their completion. Other systems including the Condenser Evaporation, Moisture Separator Reheater, Main Steam and Condensate systems are not explicitly included in the schedule. Further detail on these activities should be provided in additional schedules.	Two months are allowed for a flush of the turbine generator system and a month is allowed after that to complete setting the turbine on the turning gear. For the turbine generator systems, milestone dates are provided for the completion of the given systems. These systems are brought on-line within 1-2 months after the completion of the critical M&E construction activities. Based on other plant schedules, these durations are judged to be reasonable.	The completion of the turbine generator systems parallels the completion of the turbine building so the two activities finish within practical proximity of each other. Fuel load follows shortly after completion of all turbine generator buildings and components. This logic is judged to be reasonable.
Main Control Room Systems	Completion and turnover of the main control room systems is not explicitly included in this schedule.	N/A	N/A

Activity	Scope	Duration	Logic
Simulator	Activities in the simulator schedule (Reference 3.2) include GE-San Jose testing of the simulator, shipping the simulator from GE-San Jose to the construction site, and installing simulator equipment in the Training Center Building. This scope is judged to be reasonable.	The schedule allows for approximately 18 months for GE testing, 1 month to ship the simulator, and approximately 2 months to install the simulator on-site. Although little information is available regarding past experience with simulator installation, based on engineering judgment these durations are thought to be reasonable.	These events follow logically from the completed manufacturing of the simulator. This logic is judged to be reasonable.
Radwaste Systems	Completion and turnover of radwaste systems is not explicitly included in this schedule.	N/A	N/A
Electrical Systems	The schedule includes activities for the construction of Power Block Field Installed Commodities for the electrical systems. This scope is judged to be reasonable.	The durations assigned for the construction of the Electrical Systems are approximately the following: - Concrete Installation = 26 mo - Cable Tray Installation = 23 mo - Large Bore Piping Installation = 27 mo - Conduit Installation = 30 mo - Small Bore Piping Installation = 26 mo - Cable Installation = 22 mo Based on past construction experience, these durations are judged to be reasonable for the completion of the Electrical Systems.	Electrical Systems are installed while there is good access to underground spaces and are completed prior to Reactor Pre-Operational Testing. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Water Treatment Systems	Activities related to Water Treatment Systems include construction of safety and non-safety intake structures, a makeup water treatment building, underground piping, and aboveground storage tanks. This scope is judged to be reasonable, though more detail will be required in more detailed schedules.	The durations assigned for the construction of some of the major components of the Water Treatment Systems are approximately as follows: - Safety-Intake Building = 20 mo - Make-up Water Treatment Building = 13 mo - Service Water Tunnel = 10 mo - Circulation Water Piping = 6 mo - Demin Water Storage Tank = 3 mo - Filtered Water Storage Tank = 3 mo Based on past construction experience, these durations are judged to be reasonable for the completion of the Water Treatment Systems.	The Water Treatment Systems are installed at appropriate times during the construction schedule when there is good access to the required spaces. Water Treatment is completed relatively early compared to plant start-up.
Other Plant Systems	This scope includes the cooling tower, fire protection system, and machine shop. This scope is judged to be somewhat limited, however, other activities may be included in some of the broad terminology of the PSS.	The durations assigned for the completion of the other plant systems are approximately the following: - Cooling Tower = 18 mo - Fire Protection System = 7 mo - Machine Shop = 10 mo Based on past construction experience, these durations are judged to be reasonable for the completion of the other plant systems given.	The cooling tower and machine shop are built in parallel with other plant construction activities as labor is available.

References and Notes:

a. Unless otherwise noted, schedule information comes from Appendix F of Reference 3.1.
b. Reference 3.2

Table B-5. GE ESBWR Schedule Evaluation
Start-up and Commissioning Phase

Activity	Scope	Duration	Logic
A. System Testing and Qualification[a]			
Transformers and Switchyard	Activities related to the system testing and qualification of the Transformers and Switchyard include the startup and testing of the auxiliary electric system. This scope of work is judged to be reasonable.	The duration assigned for the startup and testing of the auxiliary electric system is 4 months. This duration is judged to be reasonable based on historical plant schedules.	The startup and testing of the auxiliary electric system follows the installation of all structural steel in the turbine building and precedes the energization of the entire auxiliary electric system. This logic is judged to be reasonable.
Reactor Systems	Reactor Systems testing is included in the schedule. Although the PSS is somewhat vague about what tests will be performed, this scope of work is judged to be reasonable. It is expected that a more detailed scope of work is available on other schedules.	The duration assigned for reactor systems testing and qualification is 7 months. This duration is on the shorter side of durations that were previously achieved; however, it is judged to be reasonable based on the simplification of the ESBWR reactor systems relative to other plants.	The systems testing begins as soon as M&E construction is completed in various parts of the reactor building. The testing is completed prior to the Reactor Pre-Operational Tests.
Safety Systems	Testing of the safety systems is not explicitly included in the PSS. The testing of these systems is assumed to be included in the testing of other major systems such as the reactor building and turbine building.	N/A	N/A
Turbine Generator Systems	Turbine Generator Systems testing is included in the schedule. Although the PSS is somewhat vague about what tests will be performed, this scope of work is judged to be acceptable. It is expected that a more detailed scope of work is available on other schedules.	The duration assigned for turbine generator systems testing and qualification is 12 months. This duration is judged to be reasonable based on historical plant schedules.	The systems testing begins as soon as M&E construction is completed in various parts of the turbine building. The testing is completed prior to the LOOP/LOCA Tests.
Main Control Room Systems	Main Control Room Systems testing is included in the schedule. Although the PSS is somewhat vague about what tests will be performed, this scope of work is judged to be acceptable. It is expected that a more detailed scope of work is available on other schedules.	The duration assigned for main control room systems testing and qualification is 11 months. This duration is judged to be reasonable based on historical plant schedules.	The systems testing begins as soon as M&E construction is completed in various parts of the turbine building. The testing is completed prior to the Reactor Pre-Operational Tests.

Activity	Scope	Duration	Logic
Simulator	Activities in the simulator schedule (Reference 3.2) include site simulator acceptance tests. Although this activity is somewhat vague, this scope of work is judged to be acceptable. It is expected that a more detailed scope of work will be available on other schedules.	The schedule allows for approximately 3 months for simulator acceptance tests. This duration is judged to be reasonable based on engineering judgment and limited historical schedule information.	As the simulator schedule is not tied to the PSS, relationships to overall project schedule cannot be determined. The PSS notes fuel load in the middle of year 7, while the simulator schedule puts fuel load at the beginning of year 6. The internal logic of the simulator schedule seems reasonable for the testing of the simulator.
Radwaste Systems	Radwaste systems testing is included in the schedule. Although the PSS is somewhat vague about what tests will be performed, this scope of work is judged to be acceptable. It is expected that a more detailed scope of work is available on other schedules.	The duration assigned for radwaste systems testing and qualification is approximately 5 months. This duration is judged to be reasonable based on historical schedule information.	The radwaste systems testing begins as soon as M&E construction is completed in various parts of the turbine building. The testing is completed prior to the Reactor Pre-Operational Tests.
Electrical Systems	Testing of the electrical systems is not included as a discrete activity on the PSS. The testing of these systems may be included in the testing of other major areas such as the reactor building, control building, and turbine building.	N/A	N/A
Water Treatment Systems	Testing of the water treatment systems is not included as a discrete activity on the PSS. The testing of these systems may be included in the testing of other major areas such as the reactor building, radwaste building, and turbine building.	N/A	N/A
Other Plant Systems	The testing of other plant systems is not explicitly discussed in this schedule.	N/A	N/A
B. Fuel Loading[a]			
Fuel Loading	The schedule includes activities related to fuel loading during the unit startup phase. This scope is judged to be reasonable.	The duration assigned for fuel loading is 1 month. This duration is judged to be reasonable based on the start-up plans for other nuclear plants.	Fuel loading follows all ITAAC and leak testing performed during the pre-fuel load startup phase. Following fuel load, a series of tests are performed to confirm performance and heatup. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
C. Final Commissioning[a]			
Final Commissioning	The schedule includes activities related to the final testing sequences required prior to commercial operation. These tests include: open vessel pre-critical testing, nuclear heatup testing to 5% power, low power testing at <25%, mid power testing at 50 to 75%, high power testing at 100% power, and performance testing.	The duration assigned for final commissioning tests is 6 months. This duration is judged to be reasonable based on prior plant start-up experience (Reference 1.5).	Final commissioning tests proceed logically following the loading of fuel. The tests are gradually increased to higher and higher power levels to test the capabilities of the plant. Once all tests have been completed and passed, the plant is ready for commercial operation. This logic is judged to be reasonable.

References and Notes:

a. Unless otherwise noted, schedule information comes from Appendix F of Reference 3.1.

Table B-6. GE ESBWR Schedule Evaluation
Training Phase

Activity	Scope	Duration	Logic
A. Operator Training[a]			
Operator Training	The schedule includes activities related to operator training such as: assigning operator personnel, operator training, the availability of vendor training information, and preparation of the operator training manual. This scope of work is judged to be reasonable.	The durations assigned for some of the major portions of operator training are approximately the following: - Assign Operator Personnel = 7 mo - Operator Training = 30 mo - Training Manual Preparation = 7 mo Based on engineering judgment, these durations are judged to be reasonable for the training of the operators.	The operator training follows the assignment of the operator personnel and the availability of the training materials. The training manual is completed in parallel with the beginning of operator training. All training is completed prior to Reactor Pre-Operational Tests (10 months prior to fuel load).
B. Operator Training on Simulator[a]			
Operator Training on Simulator	Activities in the simulator schedule (Reference 3.2) include operator training on the simulator. This scope of work is judged to be reasonable.	The schedule allows for approximately 18 months for operator training on the simulator. Based on engineering judgment, this duration is judged to be reasonable.	Operator training on the simulator begins 1 year prior to fuel load and continues for 6 months after fuel load. This logic is judged to be reasonable.

References and Notes:

a. Unless otherwise noted, schedule information comes from Appendix F of Reference 3.1.

Table B-7. GE ESBWR Schedule Evaluation
Licensing and ITAAC Phase

Activity	Scope	Duration	Logic
A. Pre-Fuel Load			
Engineering Reviews	Engineering Reviews pre-fuel load are not explicitly included in the schedule.	N/A	N/A
Module Shop Inspections	Module Shop Inspections are not explicitly included in the schedule.	N/A	N/A
On-site Construction Inspections	On-site construction inspections are not explicitly included in the schedule.	N/A	N/A
Testing and Qualification Reviews	Testing and Qualification Reviews are not explicitly included in the schedule. A milestone is noted for NRC ITAAC 100% Acceptance; however, the scope of what these acceptance reviews are and the duration required to complete them does not appear to be included.	N/A	N/A
B. Post-Fuel Load			
Engineering Reviews	Engineering Reviews post-fuel load are not explicitly included in the schedule.	N/A	N/A
On-site Construction Inspections	On-site Construction Inspections are not explicitly included in the schedule.	N/A	N/A

References and Notes:

a. Unless otherwise noted, schedule information comes from Appendix F of Reference 3.1.

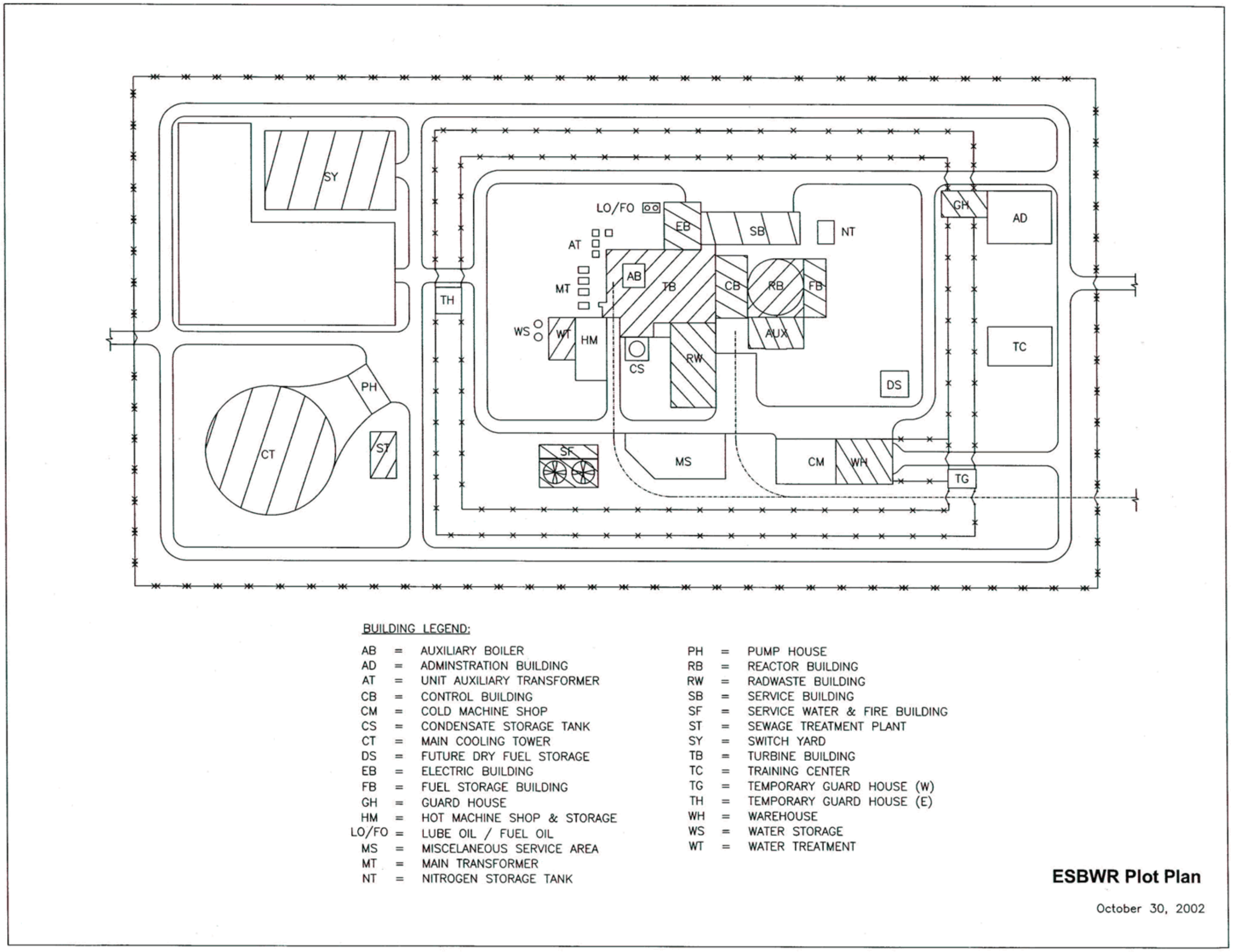

Figure B-1. ESBWR Plot Plan

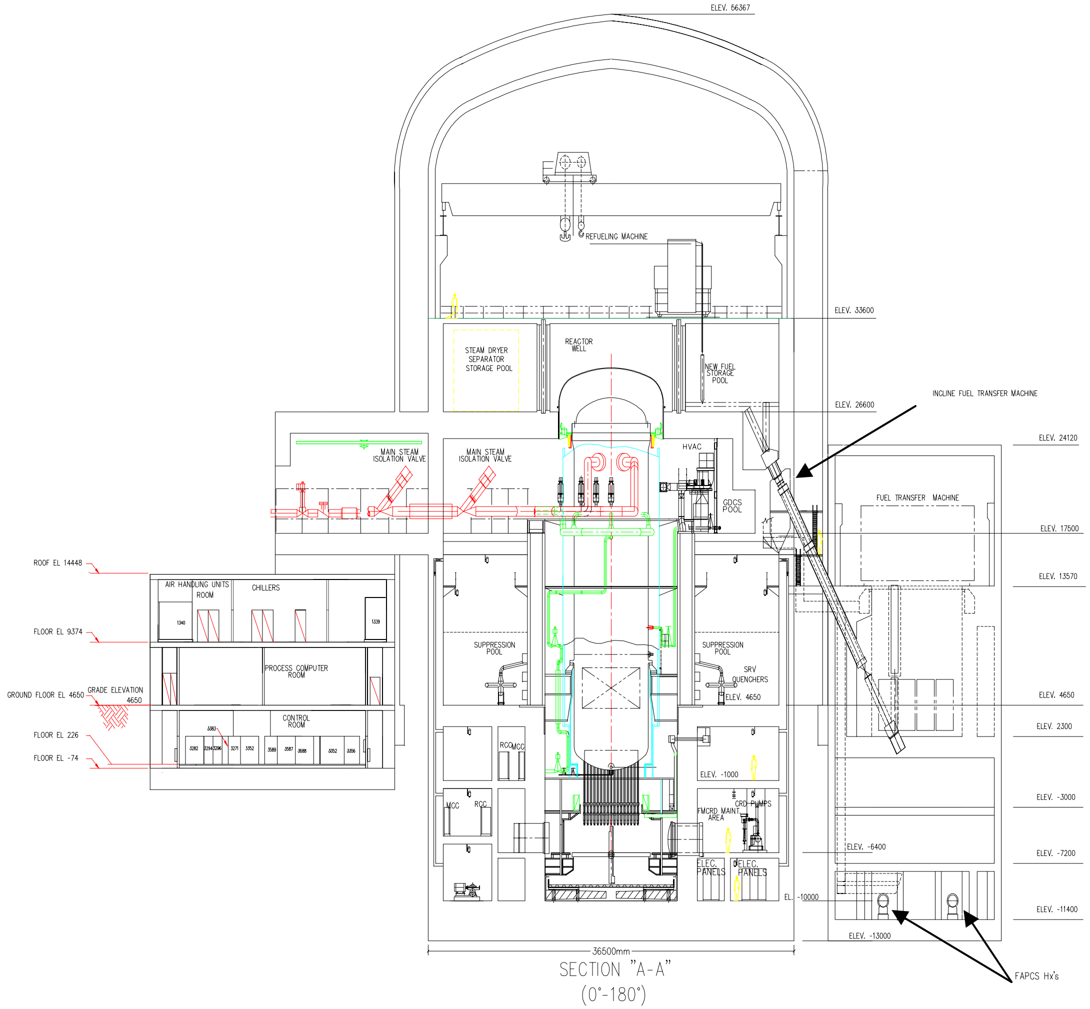

Figure B-2. ESBWR Reactor Building Elevation View
(Reference 3.4)

C

AECL ACR-700

1. BACKGROUND

The ACR-700 is designed to be an evolutionary enhancement of previous CANDU reactor designs, specifically the CANDU 6. AECL based the ACR-700's enhancements on their in-depth knowledge of CANDU systems, components and materials, as well as the experience and feedback of owners and operators of CANDU plants. The ACR design retains the proven strengths and features of CANDU reactors, while incorporating innovations and state-of-the-art technology. Improvements in economics, inherent safety characteristics, and performance can be recognized with the new design, while retaining the proven benefits of the CANDU family of nuclear power plants.

AECL used Primavera Project Planner for Enterprise (P3e) to develop a series of logic-driven schedules that integrate all of the project phases (e.g., licensing, procurement, construction, and commissioning) leading up to the commercial operation of the first of a two-unit ACR-700 station. The schedules that were reviewed as part of this construction schedule evaluation are listed below with a brief description of their content. The first two schedules, which overview the construction of a FOAK unit and an NOAK unit, are Level 1 schedules. These schedules provide little detail, but are useful for evaluating the general flow of the project. The remaining schedules are Level 2 schedules. These schedules are for the construction of a FOAK unit and provide significantly more detail than the Level 1 schedules.

- ACR-700 1st Unit Level 1 Project Schedule (Figure 2.5-4 of Reference 4.1) – This schedule provides an overview of the licensing and construction of the nuclear steam plant, common plant, and the balance of plant for a FOAK unit. This schedule was primarily used as a reference for the FOAK vs. NOAK evaluation (Section 6 of this appendix).
- ACR-700 Nth Unit Level 1 Project Schedule (Figure 2.6-3 of Reference 4.1) – This schedule of an NOAK unit is similar in scope to the FOAK schedule. However, the overall project duration is decreased as detailed in Section 6 of this appendix.
- ACR-700, U.S. Licensing, Level 2 Schedule (Appendix C of Reference 4.1) – This schedule outlines the licensing of the ACR-700 plant in the U.S. Specific information is provided for licensing the plant at Dominion's North Anna site and TVA's Bellefonte site. This schedule was primarily used as a reference for the schedule assumptions discussion (Section 2 of this appendix).

- ACR-700, NSP Engineering, Design Engineering, Level 2 Schedule (Appendix D of Reference 4.1) – This schedule provides the engineering activities associated with design, procurement support, construction support, and commissioning of the nuclear steam plant (NSP) buildings and systems. This schedule was primarily used as a reference for the detailed schedule evaluation (Section 3 of this appendix).
- ACR-700, Major Procurement, Level 2 Schedule (Appendix E of Reference 4.1) – This schedule provides the activities associated with procurement of the major equipment in the NSP systems. This schedule was primarily used as a reference for the detailed schedule evaluation (Section 3 of this appendix).
- ACR-700, Construction, Level 2 Schedule (Appendix F of Reference 4.1) – This schedule provides the activities associated with the construction of the NSP buildings and systems. This schedule also covers the procurement, construction, and turnover/commissioning of the BOP buildings and systems. This schedule was primarily used as a reference for the detailed schedule evaluation (Section 3 of this appendix).
- ACR-700, Commissioning, Level 2 Schedule (Appendix G of Reference 4.1) – This schedule provides the activities associated with the commissioning of the NSP equipment and systems. This schedule was primarily used as a reference for the detailed schedule evaluation (Section 3 of this appendix).
- ACR-700, Critical Path, Level 2 Schedule (Appendix H of Reference 4.1) – This schedule illustrates several of the critical and near critical paths in the construction of the ACR-700 plants. This schedule was primarily used as a reference for the critical path evaluation (Section 5 of this appendix).
- ACR-700, Modularization and Integration (Modules), Level 2 Schedule (Appendix I of Reference 4.1) – This schedule provides the activities associated with design, fabrication, and analysis of the modules. This schedule was primarily used as a reference for the detailed schedule evaluation (Section 3 of this appendix).
- Summary Schedule for Simulators Manufacturing, Installation, and Training (Reference 4.4) – This schedule provides the activities associated with procurement, installation, and testing of the simulator. Activities associated with operator training are also included in the schedule. This schedule was primarily used as a reference for the detailed schedule evaluation (Section 3 of this appendix).

As previously mentioned, the schedules listed above are for the construction of the first of a 2-unit station. AECL claims that the second ACR-700 unit would be completed 12 months after the first (see Figure C-1). However, a construction schedule was not provided for this unit.

Because an ACR-700 plant has never been built, the primary benchmarks used to evaluate the ACR-700 schedule are from CANDU 6 projects, specifically the Qinshan project. This station consists of two units constructed in China. The first unit completed in January 2003 and the second in July 2003. This construction project employed some of the advanced construction technologies (e.g., modularization and open-top construction) that AECL plans to expand upon during the construction of the ACR-700 plants. Table C-1 compares important milestones on the ACR-700 critical path to those achieved during the construction of the Qinshan plant (the Qinshan data is from Reference 4.2 and the ACR-700 data is from Reference 4.1).

Table C-1. Milestone Comparison between ACR-700 and Qinshan

Milestone	Qinshan Actual Date	ACR-700 Planned Date
Contract Effective Date	0	0
Start Excavation	1	6
First Containment Concrete	16	12
Calandria & Pressure Tubes Delivered to Site	28	26
Reactor Moved into Reactor Building	33	33
PHT Pumps Delivered to Site	37	36
PHT Main Circuit Turnover	56	45
PHT Hydrotest Complete	60	49
Start Fuel Load	65	52
First Criticality	67	56
Unit Complete	71	60

1.1. Plot Plan

In order to provide the reader with a general overview of the plant layout, a plot plan from Reference 4.1 is provided in Figure C-4.

1.2. Systems and Equipment

The major systems and equipment of the AECL ACR-700 are organized by building and included below:

Reactor and Reactor Auxiliary Buildings

- Reactor Assembly
  - Calandria
  - Reactivity Mechanisms
- Moderator Systems (heavy water)
- Heat Transport Systems (light water)
  - Steam Generators
  - Heat Transport Pumps
- Fuel Handling Systems
  - New and Spent Fuel Transfer Systems
  - Spent Fuel Storage System
- Steam and Feedwater Systems
  - Main Steam System
  - Main Feedwater System
  - Emergency Feedwater System

- Recirculated Cooling Water System
- Liquid Radioactive Waste Management System
- Safety Systems
  - Safe Shutdown Systems
  - Emergency Coolant Injection System
  - Long-term Cooling System

Turbine Building

- Steam Turbine
- Generator
- Condenser

Main and Secondary Control Buildings

- Distributed Control System
- Plant Display and Monitoring Systems
- Post-Accident Management System

Pumphouses

- Condenser Cooling Water System
- Raw Service Water System

2. ASSUMPTION IDENTIFICATION

Detailed assumptions for each of the categories identified in Section 1.4.1 are presented below. Figure C-1 was generated to represent the relationships that AECL assumed between licensing, commercial, and construction milestones.

2.1. Fundamental Project Assumptions

1. The ACR-700 schedule is for the FOAK plant built in the U.S. Therefore, extra time (as compared to the NOAK schedule) is included in the schedule for engineering, licensing, and resolving unanticipated issues.
2. Project mobilization and pre-project engineering will start 18 months and 12 months prior to the Contract Effective Date (CED), respectively.
3. No resource limitations have been applied to the schedule.

2.2. Licensing and Permitting Assumptions

4. The Safety Evaluation Report (SER) is issued three months prior to CED.
5. The Early Site Permit (ESP) is required prior to site preparation (i.e., prior to CED).
6. Design Certification is issued three months after CED.
7. The Combined Construction and Operation License (COL) will be approved 32 months after the application is submitted. That is, the NRC review of the COL application and the public hearings will be completed in a 32-month period.
8. The COL approval is required prior to pouring first concrete (i.e., 12 months after CED).

2.3. Site-Specific Assumptions

9. The reference site is the Bellefonte Nuclear Power Plant site located in Jackson County, Alabama.
10. The nuclear power plant site is accessible by water, either on the coast or on a navigable river. This assumption is a requirement for the transportation of the Calandria and Shield Tanks Assembly (CSTA) and is preferable for the transportation of some of the larger modules.
11. A suitable Very Heavy Lift (VHL) crane is available at the site. It will be used to place all modules and all large sections of the containment structure perimeter wall and dome steel liners.

2.4. Engineering and Procurement Assumptions

12. Release for Fabrication (RFF) packages will be prepared and issued to the fabrication shops 12 months before the start of fabrication.
13. No purchase orders will be issued prior to the CED (with the exception of those mentioned in Assumption 19). However, procurement activities (e.g., vendor evaluations and bid evaluations) will proceed during the pre-project and mobilization period.
14. Pre-qualification of module fabricators is assumed to be completed in time to award the major/critical modules at the CED.
15. Material contracts for critical equipment will be pre-negotiated, which allows for the purchase orders to be ready to issue at CED and for manufacturing to start very early in the project.
16. The manufacturing duration for the simulator is assumed to be 18 months.
17. Manufacturing durations for key equipment were based on those achieved during the Qinshan project and discussions with prospective suppliers.
18. Some of the major equipment to be installed in the plant will be manufactured, assembled, and shipped to the site in slightly less time than what has been achieved with similar equipment on past projects. Manufacturing and procurement practices necessary to meet these requirements are being assessed.
19. The pre-ordering of long delivery components (e.g., nuclear piping, nuclear pumps, and nuclear valves) is planned for the fabrication of critical modules. These materials will be bulk ordered close to CED and delivered directly to the module fabricator. This process, known as "free issue of material," will be applied whenever late delivery of material would impact delivery of a module.
20. The CSTA will be fabricated in Canada at a location with access to navigable water.
21. The estimated duration for the fabrication of a module is four to six months, depending on complexity.
22. The estimated duration for the delivery of a module to the site is two months maximum.

2.5. Construction Assumptions

23. Release for Construction (RFC) packages will be issued to field construction forces 9 months before a module is lifted in place.

24. Verification, check-out, and testing of each system will be performed when all components are installed (mechanically complete) and before the system is turned-over to the commissioning group.

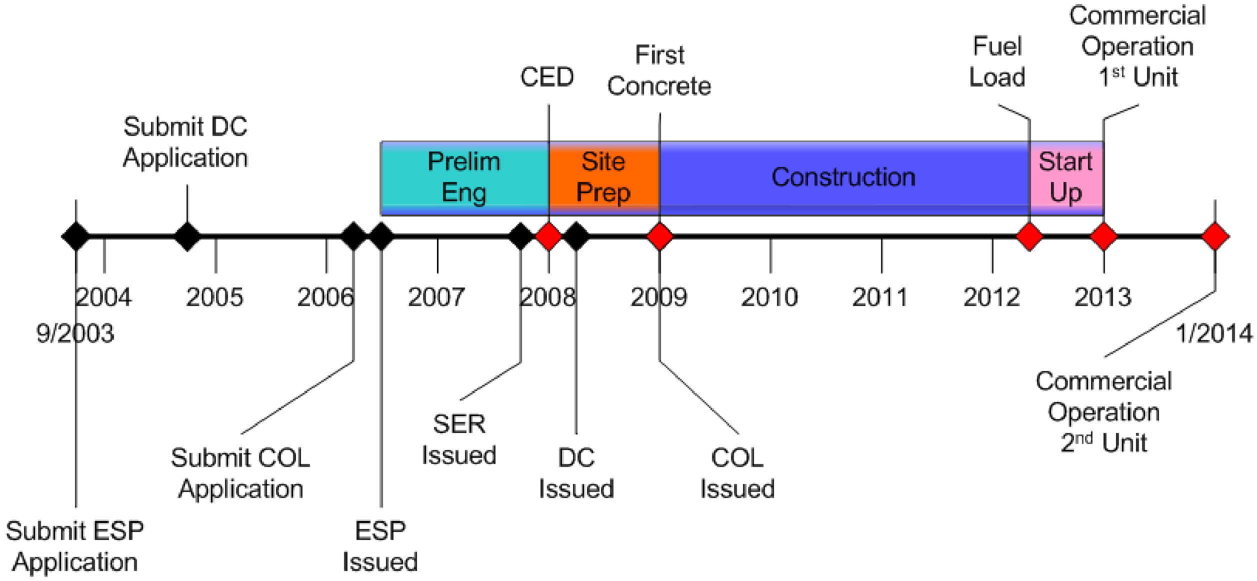

Figure C-1. ACR-700 Licensing and Construction Timelines

3. DETAILED SCHEDULE EVALUATION

A detailed evaluation was performed using the approach described in Section 1.4.2 on the following phases of the ACR-700 schedule: Engineering, Procurement, Construction, Start-up and Commissioning, Training, and Licensing Inspections and ITAAC. The results of the detailed evaluation are provided in Tables C-2 through C-7 and summarized below.

3.1. Engineering

Scope

AECL assumes that they have not obtained a Design Certification for the ACR-700 prior to CED. Therefore, much of the engineering scope is in support of obtaining the Design Certification and, subsequently, the COL. The engineering schedule includes activities for the performance, review, and approval of preliminary and detailed design work products. Activities associated with the engineering of the modules are also included.

One significant engineering activity that is not included in the schedule is the design of the simulator. It is recommended that this scope be defined so that its impact on the schedule can be evaluated.

Duration

The engineering design work required to support DC, COL, and fabrication is completed over a 51-month period. This amount of time is expected to be sufficient to complete the engineering work. Additionally, it is likely that time could be made up by augmenting the engineering staff in the event that engineering activities begin to fall behind schedule. Therefore, this duration is judged to be reasonable.

Logic

AECL assumed that the site-specific engineering activities would commence 12 months prior to CED. Because of the potential uncertainty and complexity of the commercial agreements associated with a FOAK nuclear construction project, it is unclear how much effort an owner would be willing to invest prior to CED. Therefore, there is some risk associated with this logic.

Similarly, a large part of this work is scheduled to occur prior to achieving important licensing milestones including ESP, DC, and COL. Because of the uncertainty in the licensing process, it is unclear how much effort an owner would be willing to invest prior to achieving these milestones. Therefore, there is some risk associated with this logic.

An engineering approval or release (e.g., Release for Fabrication, Release for Construction) is generally the last step in a string of engineering activities. Fabrication and Construction activities were reviewed to verify that they did not proceed before the engineering release was received. No discrepancies were identified during the review.

3.2. Procurement

Scope

The schedule includes activities for the procurement of long-lead items, bulk order materials, and modules. Activities for the transportation of equipment and materials to the module fabrication shops and the job site are also included. Once the modules arrive on site, module preparation activities are conducted.

The level 2 schedule provided by AECL does not include any of the expected activities for shop-testing and qualification. The documentation that AECL provided does discuss these activities, although there is insufficient data for a thorough evaluation. It is possible that AECL considered the shop-testing activities to be part of the equipment and module fabrication activities when estimating the fabrication durations. If not, the performance of these activities could have an impact on the overall schedule as several long-lead procurements are on the critical path. Also, AECL and their vendors may have relatively little experience with NRC inspections and U.S. code requirements, which could result in schedule delays for shop testing and qualification.

Duration

The procurement durations used in the schedule for long-lead items and bulk materials are based largely on the experience at Qinshan and discussions with potential suppliers. However, AECL claims that some of the major equipment must be manufactured and shipped in less time than what was previously achieved. AECL is working to establish methods and procedures to achieve the shorter durations. If they are not successful, some of these durations may increase.

AECL assumes an 18-month duration for the manufacturing of the simulator. However, they do not provide a justification for this duration. It is recommended that this assumption be further evaluated to ensure that the duration is achievable.

The durations for the module work are based on the Qinshan experience as well as constructability evaluations that have been performed. These durations of four to six months, based on module complexity, appear to be reasonable. However, it is not clear in the available documentation that a detailed review of the major modules has been conducted to evaluate fabrication durations. Therefore, there is some risk associated with these durations.

Logic

Bid evaluations and other procurement activities are performed prior to CED and some of the major licensing milestones. The risk associated with this logic is discussed in Section 3.1 of this appendix.

The only materials that are currently planned to be manufactured prior to CED are some of the bulk materials needed to fabricate critical modules. However, it may be necessary to pre-order other critical equipment if procurement durations increase (as discussed above) in order to support the schedule. It is important that a more confident estimate of procurement durations be obtained to ensure that these activities do no impact the critical path.

The relationship between engineering, procurement, and construction activities were reviewed to ensure that reasonable logic was used. No major discrepancies were identified during the review. However, it should be noted that many of the module fabrication activities are conducted in parallel. This parallel activity presents a management challenge. To address this issue, AECL intends to manage each module as a “mini-project.” This will help to ensure that module fabrication is properly monitored and managed such that it does not impact the critical path.

The logic associated with the manufacturing of the simulator is a potential point of risk. The schedule shows the simulator being completed and shipped before most of the equipment in the plant, including the Control Centre, is completed and tested. Without the test data, it is difficult to be certain that the simulator will accurately model the plant. Consequently, it may be necessary to make changes to the simulator when the test data become available. These changes could cause simulator commissioning and software verification activities to be extended.

3.3. Construction

The construction phase of the schedule includes site preparation, building construction, and system completion/turnover activities.

Scope

Site preparation is listed in the schedule as a single activity, but does not identify specifics. However, detailed site preparation activities, such as road construction, security construction, warehouse construction, temporary office space, etc., are included in Section 2.2.1.7 of

Reference 4.1. Therefore, it is assumed that AECL considered these details when they assigned the duration for the site preparation activity.

Building construction activities are organized by building. Typical activities for each building include: excavation, concrete foundation, placement of internal and external structures, assembly of pre-fabricated modules, installation of equipment, and mechanical/electrical/I&C connections. The activities for larger buildings, such as the reactor building and reactor auxiliary building, are further divided by compartments. For example, the reactor building is divided into thirteen vertical installation compartments (see Figure C-2), and detailed activities are provided for each compartment.

Construction schedule information is not provided for several buildings (i.e., administration building and radioactive waste special garage). However, these buildings are discussed in AECL documentation and shown in Figure C-4, taken from Reference 4.1. Additionally, the effort required to complete these buildings is not expected to be as significant as some of the other construction activities (e.g., the Reactor Building and Turbine Building), and it is unlikely that they would impact the critical path.

Plant system completion and turnover activities are organized by building. These activities typically include the verification, check-out, and testing of the system prior to plant-wide system commissioning and testing.

Duration

The schedule includes 6 months between the start of excavation activities and first concrete. This schedule is more aggressive than the 15 months that were achieved at Qinshan (see Table C-1). In Reference 4.2, it is stated that the Qinshan site footprint was small and a portion of one of the neighboring mountains had to be removed to increase the available space. This may be the reason the Qinshan excavation period was extended. However, it is recommended that the 6-month schedule be reevaluated to ensure that it is achievable.

The construction durations for the three most complex buildings, the Reactor Building, Reactor Auxiliary Building, and Turbine Building, are 36, 36, and 34 months respectively. This construction duration is more aggressive than what was achieved at Qinshan by about nine months (see Table C-1). AECL claims that this time savings is a result of the increased modularization and prefabrication (see Section 2.1.3 of the report for a discussion on modularization). It appears that AECL has put significant effort into analyzing the construction sequence; and, therefore, this duration is judged to be reasonable. However, as discussed in Section 2.1.3 of the report, there is some risk associated with the fact that this technology has never been implemented in the U.S. for the construction of a nuclear plant.

Durations required for completing and commissioning reactor systems, safety systems, and turbine generator systems, are approximately 12 months each. For all other systems, such as transformers, main control room systems, radwaste systems, the duration is approximately one month each. These durations appear to be consistent with what was achieved at Qinshan and during previous projects in the U.S.

Logic

The construction logic for the ACR-700 combines open-top construction and a modular approach to allow for a more efficient construction schedule. Open-top construction allows for the walls of the containment structure to be erected without enclosing the top. Through the use of a Very Heavy Lift (VHL) crane, modules and other equipment can then be lifted and lowered through the open top. This allows for much easier access to the containment building then with traditional construction techniques.

Buildings and systems that require significant effort commence earlier in the construction schedule and as labor becomes available, other buildings and systems are constructed. For each activity identified in Table C-4, the schedules for procurement, construction, and commissioning were reviewed to ensure that there is a logical sequence between the preceding and succeeding project phases. Overall, the general relationships between the activities appear to be reasonable.

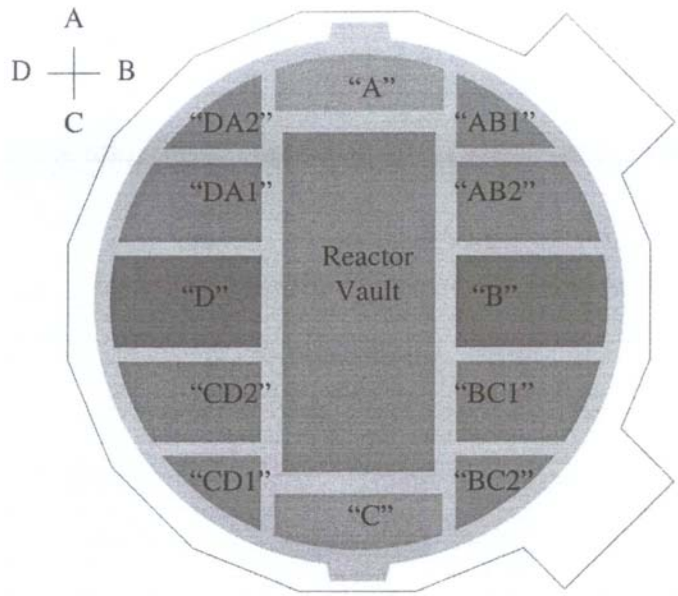

Figure C-2. ACR-700 Reactor Building
Vertical Installation Compartment Method

3.4. Start-up and Commissioning

Scope

The schedule includes activities for the commissioning of all major plant systems. Activities for loading the fuel and bringing the plant up to power are also included. Finally, the schedule indicates that integrated tests, including warranty tests, will be conducted with the plant at power before the unit is declared complete. This scope is judged to be reasonable.

Duration

The commissioning durations range from three to 18 months depending on the complexity of the system. These durations appear to be consistent with what was achieved at Qinshan and previous projects in the U.S. and are judged to be reasonable. One exception is for the commissioning of the Primary Heat Transport (PHT) system. Unlike the CANDU 6, the ACR-

700 uses light water in the PHT system. This eliminates several support systems and simplifies the commissioning of the PHT system. Therefore, AECL plans to commission the PHT system in 7 months as opposed to the 9 months that were achieved at Qinshan (see Table C-1). This duration is judged to be reasonable.

The time between start of fuel load and unit completion is 8 months. This task was completed in six months during the Qinshan project (see Table C-1). Although AECL does not provide a rationale, this extra time may have been added to allow for design issues that are unique to the ACR-700 (as compared to the CANDU 6) or for regulatory reviews. This duration is judged to be reasonable.

Logic

Generally, system commissioning activities begin as soon as system turnover is complete and most are complete prior to fuel load. The logic from the completion of commissioning activities through fuel load and final testing to unit completion was reviewed and judged to be reasonable.

Simulator software verification is conducted on-site and preceded by simulator installation and commissioning. This represents a deviation from what has been done in the U.S. Simulator software verification has generally been completed at the vendor's location before the simulator is shipped to the site. This logic has been preferred because it allows the vendor to employ its full staff of programmers, I&C technicians, and system engineers to correct any errors that are identified during software verification. Once on-site, the vendor will likely be operating with a limited staff (as compared to the staff available at their own site), and their experts may not be readily available to efficiently correct errors. The simulator software verification process could be extended as a result. The logic that AECL has provided (i.e., software verification being conducted on-site) was chosen to allow the training program to be prepared in parallel with software verification activities. This was done to prevent simulator development and training activities from affecting the critical path. This logic may be appropriate if the simulator vendor is able to establish a high level of confidence that minimal errors will be identified during the software verification process. Otherwise, there is a risk that simulator development and training could impact the critical path as there is only 1 month of float associated with these activities.

3.5. Training

Scope

The schedule includes activities for the recruitment of training staff, training program development, and operator training. This scope is judged to be reasonable.

Duration

The NRC requires that the operator training program be in place a minimum of 18 months before fuel load. This requirement is met by the AECL schedule. This duration is judged to be reasonable.

Logic

Generally, training activities are preceded by the commissioning and software verification of the simulator. Training activities are succeeded by Fuel Load. This logic is judged to be reasonable.

3.6. Post-COL Licensing and ITAAC

The schedule provided in Reference 4.3 provides a single activity for performing ITAAC that has a duration of two years. However, it is not clear what this activity is referring to or how it ties into the rest of the schedule. Therefore, a detailed evaluation of this schedule could not be performed. The potential implications of this issue are discussed in Section 2.1.4 of the report.

4. IMPACT OF MODULARIZATION

The modularization techniques proposed for the ACR-700 are based on the experience and established work processes of recent CANDU projects: four CANDU units were built in the 1990's, Qinshan Phase III Unit 1 went into service in December 2002, and there are two units currently under construction. Like previous plants, AECL plans to use Hitachi machine shops and satellite offices located in Japan, Canada, and the U.S for the ACR-700.

The approach for modularization of the ACR-700 involves the use of four module types:

1. Multi-discipline modules with process equipment, piping, cable trays, ducting, civil structures, instruments, etc.;
2. Process equipment and piping modules with equipment, piping, and structural frame;
3. Piping modules with piping, supports, and structural frame; and
4. Instrumentation, Controls, and/or Electrical (ICE) modules with panels, cabinets, racks, and cable trays.

The design packages for the modules are an evolution of the methods that were used at Qinshan. The Qinshan design packages were produced by area (location) by different engineering groups (civil, mechanical, piping, etc.). AECL plans to produce the design packages for the ACR on parallel paths: for fabrication by module with input from the engineering groups, and for construction by volume with input from the engineering groups.

AECL plans to use four alternative methods for module production:

- Modules completed in a factory and shipped to site,
- Sub-modules completed in a factory, shipped separately to the site, and final module assembly in on-site facility,
- Components fabricated in a factory, with modules fabricated in on-site facility, or
- Major equipment shipped separately to site.

The transportation methods available to the construction site will affect the module types used in the plant construction.

AECL states that the construction schedule duration will be reduced since modules will be produced in parallel with site civil work. In addition, the reactor building design is simplified and will require significantly less time to construct in part due to the integration of floors with the modules (floors will be poured in structures integrated with the modules as they are installed). In the proposed ACR design, over 80% of the reactor building is modularized. The reactor building construction will be critical path, so the risk associated with this design is that the success or failure of modularization will have a significant impact on the project schedule.

5. CRITICAL PATH EVALUATION

The ACR-700 critical path schedule spans a 60-month period and includes 132 activities. The critical path runs through the construction and commissioning of the Primary Heat Transport (PHT) system. The general flow of the critical path activities is shown in Figure C-5. The detailed critical path schedule prepared by AECL is provided in Appendix H of Reference 4.1.

Pre-Construction Phase

The first critical path activities that will be completed are related to the procurement (i.e., vendor qualification and bid evaluations) of the Feeder/Header Pipe Whip modules, Calandria module, and the Primary Heat Transport (PHT) pumps and hangers. The start date of these activities is chosen such that the purchase orders for these modules can be issued on the CED. The duration assigned for the procurement of these modules is approximately seven months for the Feeder/Header Pipe Whip modules and the PHT pumps and hangers, and approximately twelve months for the more complicated Calandria module. These durations are considered appropriate.

On the CED, the purchase orders for the Feeder/Header Pipe Whip modules, Calandria module, and the Primary Heat Transport (PHT) pumps and hangers will be issued and site preparation will commence. The fabrication of the three modules and site preparation activities will be performed in parallel and all are on the critical path. Having this many critical activities being performed in parallel represents a risk. Sufficient resources will need to be available to closely monitor and manage each of these paths concurrently. If any of the paths slip, that will have a direct, day-for-day impact on the entire project.

The duration assigned for the fabrication and transport of the modules is 27 months for the Feeder/Header Pipe Whip and Calandria modules and 36 months for the PHT pumps and hangers. AECL claims (Section 2.5.6 of Reference 4.1) that some of the major equipment will have to be manufactured, assembled, and shipped in slightly less time than what has been achieved with similar equipment on past projects. AECL is working with potential vendors to determine if the durations currently being used in the schedule are achievable. If they are not, some of the equipment may need to be ordered prior to CED in order to support the schedule. However, it is not clear that an owner would be willing to make such an investment prior to CED because of the expected commercial and licensing uncertainty (see Section 3.1 of this appendix). Therefore, an increase in procurement durations could impact the schedule.

While the modules are being fabricated, the site preparation activities will be completed followed by the construction of the reactor building foundation and walls. The time between the start of excavation to first concrete is 6 months. This schedule is more aggressive than the 15 months that were achieved at Qinshan (see Table C-1). This discrepancy, which was previously discussed in Section 3.3 of this appendix, may be attributed to details specific to the Qinshan site that required additional civil work. However, it is recommended that this duration be reevaluated to ensure that it is achievable.

Construction Phase

The construction phase of the critical path begins with the first-concrete pour. The schedule allows for one month to pour the concrete for the Reactor Building Base Slab. In order to achieve this schedule, large volume pours and prefabricated rebar will be used. Once the base slab is in place, the walls of the reactor building will be erected. One year is allocated to complete this process. This is judged to be reasonable.

The delivery of the Feeder/Header Pipe Whip modules is scheduled to occur slightly (1 month) before the Reactor Building walls are complete. This allows time for some site work to be performed on the modules to complete them. When the Reactor Building walls and the Feeder/Header Pipe Whip modules are prepared, the modules are lifted into place. Once the module is in place, activities related to pouring concrete and installing formwork are performed. These activities take place over a three-month period.

The Calandria module is installed following the installation of the Feeder/Header Pipe Whip modules. The Calandria module arrives on-site in several pieces; consequently, substantial site work is required to assemble the module before it is installed. Therefore, it is scheduled to be delivered five months before the completion of the Feeder/Header Pipe Whip modules. When the Feeder/Header Pipe Whip modules installation is complete and the Calandria module is ready, the Calandria module is lifted into place. Once the module is in place, activities associated with welding pipe are performed. These activities occur over a 1-month period.

The PHT pumps and hangers are installed when the Calandria module is complete. Limited site work is required for this equipment. Therefore, the delivery of the PHT pumps and hangers is scheduled to coincide with the completion of the Calandria module. The duration assigned for the installation of the PHT pumps and the completion of the PHT piping is seven months.

The final step of the critical path construction phase is the check-out testing and turnover of the PHT system. This is scheduled to be completed in a two-month period. Upon completion, the system is turned over to commissioning.

The planned critical path construction phase for the ACR-700 is nine months shorter than what was achieved during the construction of the Qinshan plant (see Table C-1). AECL claims that this savings is primarily a result of increased modularization and prefabrication (see Section 2.1.3 of the report for a discussion on modularization), which limits the critical path to a small number of large components. This time savings appears reasonable; however, there is risk inherent in the fact that this technology (i.e., modularization) has never been implemented by AECL on the scale that they are planning.

Commissioning Phase

The commissioning of the PHT is another area that AECL believes they can save substantial time on the critical path. They plan to complete this activity two months faster than was achieved at Qinshan (see Table C-1). As previously discussed in Section 3.4 of this appendix, this decrease in duration is associated with the removal of the heavy water, and associated support systems, from the PHT. The planned seven-month duration is judged to be reasonable.

Start-Up Phase

Once the PHT system is commissioned, the fuel is loaded, the unit is brought up to power, and final tests are performed. The eight-month startup (i.e., fuel load to completion) schedule for ACR is slightly longer than the six-months that were achieved at Qinshan (see Table C-1). As discussed in Section 2.1.4, this extra time may have been included to address new issues associated with design difference between the CANDU 6 and the ACR-700 or to allow for regulatory reviews. This is judged to be reasonable.

Near Critical Paths

Although not part of the critical path, AECL has identified the following activities that are near the critical path:

- Procurement and installation of the Control Centre Equipment
- Procurement and installation of the Main Moderator Pumps
- Procurement and installation of the Fuel Machine Carriage and Heads
- Turbine Building construction
- Simulator Development and Training

The float (relative to the critical path) associated with many of these activities was not provided in the documentation that was reviewed, so the associated risk is difficult to assess. However, it is important that resources be available to closely monitor and manage these activities to ensure that they do not impact the critical path. The pre-ordering of the equipment that is listed should be considered as an option for mitigating risk.

Critical Path Conclusions

In summary, the critical path schedule is judged to be reasonable. Additionally, AECL has recent construction experience and a proven track record for completing their projects on schedule, as exhibited in the construction of Wolsong Units 3 & 4 in Korea and Qinshan Units 1 & 2 in China.

One potential area of risk that was identified during the critical path evaluation is in the pre-construction phase. The schedule currently has four independent strings of activities on the critical path that merge during the construction phase:

1. Procurement and fabrication of the Feeder/Header Pipe Whip modules,
2. Procurement and fabrication of the Calandria module,
3. Procurement and fabrication of the Primary Heat Transport (PHT) pumps, and
4. Site preparation activities

This issue is compounded by the number of procurement activities that are on the near critical path list. It is recommended that the pre-ordering (i.e., before CED) of the critical modules be evaluated as an option for removing the procurement activities from the critical path. This would result in a single critical path running through the Site Preparation activities.

6. First-Versus Nth-of-a-Kind

The detailed Level 2 ACR-700 schedules are for a FOAK plant construction. Sections 2.5 and 2.6 of Reference 4.1 provide a macroscopic perspective of the logic driven integration schedules for a first-and nth-unit construction. The nth ACR-700 unit is considered to be the 5th unit of a series (i.e., with two complete two-unit stations). The inherent assumption between these schedules is that a significant learning curve will have taken place between the first unit and nth unit construction; and therefore, the construction duration for the nth unit will be decreased to 48 months from the 60 months that are planned for the first unit (see Figure C-3). In this section, the NOAK duration decreases are evaluated to determine if they are reasonable.

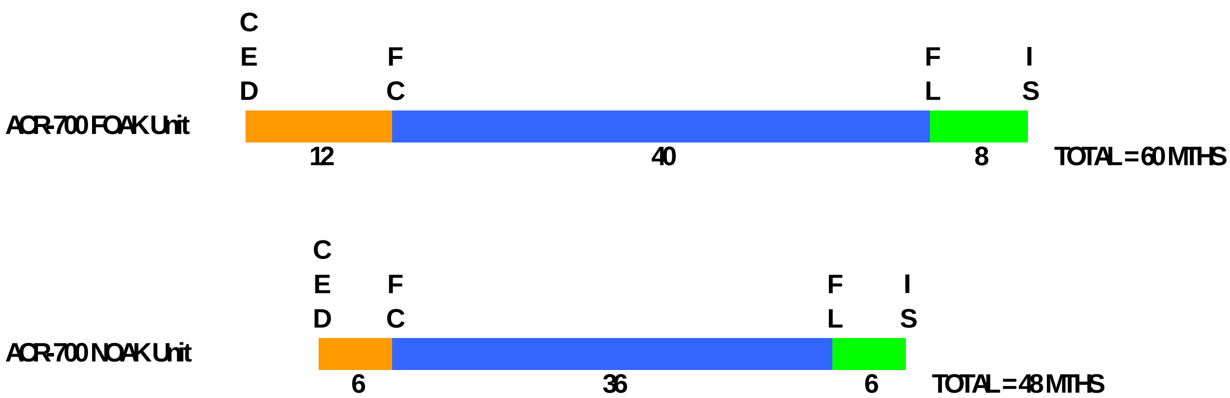

Figure C-3. ACR-700 Simplified Target Schedules
FOAK vs. NOAK Unit

Pre-Construction Phase

The FOAK schedule includes many engineering activities that will have already been completed prior to the construction of the NOAK unit. However, these activities are largely accomplished prior to CED, and, consequently, have little impact on the construction schedule.

The FOAK schedule has site preparation activities starting at the CED, followed by excavation activities. In the NOAK schedule, the site preparation activities are performed ahead of time and excavation commences on the CED. Consequently, the time between CED and first concrete can be cut in half. Because uncertainty and risk associated with commercial and licensing issues for the Nth unit are less likely, this adjustment is judged to be reasonable. However, it is unlikely that the procurement durations will decrease by six months to accommodate this change. Therefore, a significant amount of the equipment and modules may have to be procured prior to CED for the NOAK schedule to be achievable.

Construction Phase

For the NOAK unit, the construction duration from first concrete to fuel load is reduced by four months. This gain is attributed to improvements from past experiences that will have removed construction bottlenecks and any design problems. The commissioning efforts for the NOAK unit are expected to be significantly reduced since all procedures and system turnover interfaces will have been optimized through feedback from previous ACR-700 units.

Start-Up Phase

For the NOAK unit, the time between fuel load and unit completion is reduced by two months. This gain in schedule is attributed to the lessons learned during the previous start-ups. Additionally, this duration has already been achieved by AECL at Qinshan (see Table C-1).

ACR-700 1st-versus Nth-of-a-Kind Conclusions

In general, the basic assumptions and duration reductions made between the FOAK and NOAK units are judged to be reasonable.

7. SUMMARY OF VENDOR RISK ASSESSMENT BY VENDOR

Schedule risk analyses were not provided by AECL.

Table C-2. AECL ACR-700 Schedule Evaluation
Engineering Phase

Activity	Scope	Duration	Logic
A. Conceptual and Preliminary Design[a]			
Discipline Specific	The engineering activities in the schedule are organized according to discipline. Conceptual and preliminary design activities are included in the schedule for the disciplines of: Civil/Architectural, Process/Mechanical, Computer Control, and I&C/Electrical. Examples of conceptual and preliminary design activities include: site layouts, site investigation, functional schematics, and design inputs. This scope is judged to be reasonable.	The amount of preliminary design work varies depending on the discipline. In general, the durations for each discipline are as follows: - Civil/Architectural = 27 mo - Process/Mechanical = 9 mo - Computer Control = 18 mo - I&C/Electrical = 6 mo This engineering work is completed in a 27-month period. In the event that engineering activities begin to fall behind schedule, it is likely that the time could be made up by augmenting the staff. Therefore, this duration is judged to be reasonable.	Per assumption 2, the conceptual and preliminary design work commences 12 months prior to the Contract Effective Date (CED) and 15 months prior to the issuance of a Design Certification (DC). However, it is unclear how much an owner would be willing to invest prior to achieving these milestones due to commercial and licensing uncertainties. Should this assumption be invalid, the schedule could be impacted by as much as 12 months. In general, the conceptual and preliminary design activities precede the detailed design activities. This logic is judged to be reasonable. Note that the preliminary engineering associated with the air systems in the I&C/Electrical section of the schedule begin 6 months earlier than any of the other preliminary engineering activities. This discrepancy, which is likely the result of a logic error made during the creation of the schedule, does not appear to have a significant impact on the overall schedule.
Simulator	Activities related to simulator design are not included in the schedule. It is recommended that this scope be defined so that its impact on the schedule can be evaluated.	N/A	N/A

Activity	Scope	Duration	Logic
B. Detailed Design[a]			
Discipline Specific	The engineering activities in the schedule are organized according to discipline. Detailed design activities are included in the schedule for the disciplines of: Civil/Architectural, Process/Mechanical, Computer Control, Reactor and Fuel Handling, and I&C/Electrical. Examples of detailed design activities include construction site planning, building design (e.g., reactor and control buildings), system design (e.g., moderator and heavy water supply systems), software development, and component specifications. This scope is judged to be reasonable.	The amount of detailed design work varies depending on the discipline. The duration for each discipline is approximately: - Civil/Architectural = 45 mo - Process/Mechanical = 21 mo - Computer Control = 27 mo - Reactor/Fuel Hand. = 36 mo - I&C/Electrical = 18 mo This engineering work is completed in a 45-month period. In the event that engineering activities begin to fall behind schedule, it is likely that the time could be made up by augmenting the staff. Therefore, this duration is judged to be reasonable.	In general, the detailed design activities are preceded by the conceptual and preliminary design activities and succeeded by the procurement and construction activities. This logic is judged to be reasonable. Note that the detailed engineering associated with the air systems in the I&C/Electrical section of the schedule begins 6 months earlier than any of the other preliminary engineering activities. This discrepancy, which is likely the result of a logic error made during the creation of the schedule, does not appear to have a significant impact on the overall schedule
Simulator	Activities related to simulator design are not included in the schedule. It is recommended that this scope be properly defined so that its impact on the schedule can be evaluated.	N/A	N/A
Modules[b]	The engineering activities related to modules and module integration are split into two major sections: Design/Layout and Piping. Examples of Design/Layout activities include cabinet layouts, design reviews, and RFC packages. Examples of Piping activities include stress analyses, stress reports, and ISOs. This scope is judged to be reasonable.	The duration assigned for each major section is approximately: - Design/Layout = 51 mo - Piping = 30 mo This engineering work is completed in a 51-month period. In the event that engineering activities begin to fall behind schedule, it is likely that the time could be made up by augmenting the staff. Therefore, this duration is judged to be reasonable.	In general, the Design/Layout and Piping engineering activities precede the module fabrication activities. Many of the components that are used to fabricate the modules are ordered/manufactured before the module designs are finalized. However, actual fabrication of the module does not begin until the design is finalized. This logic is judged to be reasonable.

References and Notes:

a. This schedule is provided in Appendix D of Reference 4.1.
b. The detailed design of the modules is provided in Appendix I of Reference 4.1.

Table C-3. AECL ACR-700 Schedule Evaluation
Procurement Phase

Activity	Scope	Duration	Logic
A. Component Procurement[a]			
Long-Lead Items	The procurement of long-lead items associated with the Process Systems, Reactor, Heat Transport System, Auxiliary Systems, Fuel Handling Systems, Steam Generator Systems, Water Management, Control Centre, Simulator, Main Control Room, Safety Systems, Common Process and Services, HVAC, and BOP is covered in the procurement schedule. This scope is judged to be reasonable.	The duration assigned for manufacturing some of the major equipment is approximately: - Calandria = 24 mo - PHT Feed Pumps = 36 mo - Steam Generators = 33 mo - Main Condenser = 24 mo - Turbine Generator = 33 mo - Simulator = 18 mo The schedule also includes a 6-month bid evaluation and award period for the NSP equipment. Time is not included for bid evaluation and award for the BOP equipment; however, based on a review of the schedule's logic, adding these activities is not expected to impact the schedule. Per assumption 16, the duration for the procurement of the simulator is assumed to be 18 months. AECL does not provide a justification for this assumption. It is recommended that this assumption be further evaluated to ensure that this duration is achievable. Per assumption 17, the other durations are based on experience from the Qinshan project and discussions with potential suppliers. However, assumption 18 states that in order to meet the schedule, some of the major equipment to be installed in the plant will be manufactured, assembled, and shipped to the site in slightly less time than what has been achieved with similar equipment on past projects. AECL claims that the practices necessary to achieve this schedule are currently being evaluated. If AECL determines that the durations currently in the schedule are not achievable, it may be necessary to pre-order some equipment in order to support the schedule. This issue is of particular concern because several procurement activities are on the critical path.	Bid evaluations and other procurement activities are performed prior to CED. As discussed in the duration section, AECL does not currently intend to issue purchase orders until after CED unless the current procurement estimates increase. It is recommended that further work be performed to obtain a better estimate of procurement durations to ensure that these activities do not impact the plant's critical path. In general, procurement activities precede equipment transportation activities. This logic is judged to be reasonable. The logic associated with the manufacturing of the simulator is a potential point of risk. The schedule shows the simulator being completed and shipped before most of the equipment in the plant, including the Control Centre and I&C equipment, is completed and tested. Without the test data, it is difficult to be certain that the simulator will accurately model the plant. Consequently, it may be necessary to make changes to the simulator when the test data become available. These changes could cause simulator commissioning and software verification activities to be extended.

Activity	Scope	Duration	Logic
Bulk Materials	Bulk order materials including valves, pipe, and instrument hardware are included in the schedule. This scope is judged to be reasonable.	The duration assigned for the manufacturing of bulk order materials is approximately: - Valves = 21 mo[c] - Pipe/Fittings = 15 mo - Pipe Supports = 21 mo - Instrument Hardware = 18 mo The schedule also includes a 6-month bid evaluation and award period. Per assumption 17, these durations are based on experience from the Qinshan project and discussions with potential suppliers. These durations are judged to be reasonable.	Bid evaluations are performed prior to the contract effective date. Per assumption 19, the bulk materials needed for the critical modules will be ordered prior to CED to ensure that they do not impact the critical path. Purchase orders for the remaining bulk order materials will be issued at CED. This logic is judged to be reasonable. The bulk order materials are manufactured before they are transported. This logic is judged to be reasonable.
Shop-Testing and Qualification	Activities related to the testing and qualification of major equipment in the fabrication shops are not included in the schedule. However, the documentation provided by AECL does discuss testing equipment before it is shipped. Therefore, it is assumed that AECL considered the testing to be included in the manufacturing activities.	The manufacturing durations for long-lead items and bulk materials are expected to be long enough to manufacture and test the equipment and materials.	See logic for Long-Lead Items and Bulk Materials.
Transportation	Activities associated with the transport of long-lead equipment and bulk orders are included in the schedule. This scope is judged to be reasonable.	The duration assigned for the transport of bulk order materials is approximately 2 months. This duration is judged to be reasonable.	In general, activities for the transportation of long-lead items and bulk materials are preceded by manufacturing activities and succeed by either module shop fabrication or construction activities. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
B. Module Fabrication and Assembly[a]			
Shop Fabrication and Assembly	Activities associated with the fabrication of approximately 100 modules are included in the schedule. This is consistent with other documentation claiming that 105 modules will be used in the construction of the plant. This scope is judged to be reasonable.	Per assumption 21, the durations assigned for module fabrication range from 4 to 6 months. The durations were estimated based on the complexity of the module and are judged to be appropriate. In order to achieve this schedule, approximately 100 modules would have to be fabricated in a 24-month period. Therefore, between 16 and 25 modules (based on the assumed 4-to 6-month fabrication durations) would have to be fabricated in parallel during this entire 24-month period. This represents a significant amount of parallel activity and, consequently, presents a management challenge. To address this issue, AECL intends to manage each module as a "mini-project." This will help to ensure that each module is properly monitored and managed.	In general, the module fabrication activities are preceded by the delivery of the required equipment/components and succeeded by the transportation of the modules. This logic is judged to be reasonable.
Shop-Testing and Qualification	Activities related to the testing and qualification of modules in the fabrication shops are not included in the schedule. However, the documentation provided by AECL does discuss testing equipment before it is shipped. Therefore, it is assumed that AECL considered the testing to be included in the manufacturing activities.	The manufacturing durations for modules are expected to be long enough to manufacture and test the equipment.	See logic for Shop Fabrication and Assembly.
Transportation	Activities associated with the transport of modules are included in the schedule. This scope is judged to be reasonable.	The duration assigned for the transport of modules is approximately 2 months. This duration is judged to be reasonable.	In general, module transportation activities succeed shop fabrication activities and precede module site preparation activities. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
On-site Fabrication and Assembly	Activities associated with the preparation of the modules once they arrive on-site are included in the schedule. This scope is judged to be reasonable.	The duration assigned for the on-site preparation of the modules is approximately 2 months. This per-module duration is judged to be reasonable. In order to achieve the schedule, approximately 100 modules would have to be prepared on-site in a 15-month period. Therefore, between 13 and 14 modules (based on the assumed 2-month site preparation durations) would have to be prepared on site in parallel during this entire 15-month period. This represents a significant amount of parallel activity and, consequently, presents a management challenge. To address this issue, AECL intends to manage each module as a "mini-project." This will help to ensure that each module is properly monitored and managed.	In general, module site preparation activities are preceded by module transportation and succeeded by construction activities. This logic is judged to be reasonable.

References and Notes:

a. This schedule is provided in Appendix E of Reference 4.1.
b. The procurement of the materials (e.g., valves, pipe, and fittings) used in the fabrication of the modules is provided in Appendix I of Reference 4.1.
c. This is the duration assigned for the majority of the valves. Eighteen months are assigned for butterfly relief valves and 15 months for pressure regulating valves.

Table C-4. AECL ACR-700 Schedule Evaluation
Construction Phase

Activity	Scope	Duration	Logic
A. Site Preparation[a,b]			
Soil Preparation	N/A[b]	N/A	N/A
Laydown Area Preparation	N/A[b]	N/A	N/A
Storage Area Construction	N/A[b]	N/A	N/A
Equipment Assembly Area	N/A[b]	N/A	N/A
Road and Rail Construction	N/A[b]	N/A	N/A
Security Construction	N/A[b]	N/A	N/A
Temporary Office Space and Services	N/A[b]	N/A	N/A

Activity	Scope	Duration	Logic
B. Building Construction[a]			
Reactor Building (Containment Vessel, Shield Building)	Activities are included in the schedule for reactor building (RB) construction. Activities are scheduled based on a vertical installation method for thirteen compartments (see Figure C-2). Examples of activities include RB excavation, concrete pour, assembly of prefabricated containment liner and concrete and placement of internal civil structures (compartments with 2 to 4 modules), completing horizontal and vertical connections, and placement of the concrete dome. Some major equipment (e.g., steam generator, pressurizer, emergency core cooling tanks, etc.) is not installed as part of a module, but is placed during the individual compartment sequence. This scope is judged to be reasonable.	The durations assigned for the thirteen reactor building compartments (see Figure C-2) are as follows: General activities - placement of basemat, containment walls/columns – 24 months All Compartments except Reactor Vault – approximately 12 months each Reactor Vault – 20 months The total duration assigned for construction of the RB from the placement of basemat through the completion of connecting mechanical and electrical systems is approximately 36 months. This is a significant improvement over the 47-month schedule that was achieved at Qinshan (see Table C-1). AECL claims that the savings is a result of the more extensive use of modularization and prefabrication (see Section 2.1.3 of the report for a discussion on modularization). It appears that AECL has put significant effort into analyzing the construction sequence, and, therefore, this duration is judged to be reasonable.	In general, site preparation activities, module pre-fabrication, transportation, and on-site assembly activities precede RB construction activities. Procurement and delivery of long-lead items (e.g., Calandria, PHT feed pumps, and steam generators etc.) occur concurrent with RB construction activities. In general, reactor system and safety system completion and turnover activities succeed RB construction activities. This logic is judged to be reasonable.
Auxiliary Building	Activities are included in the schedule for reactor auxiliary building (RAB) construction. The RAB is a 4-story concrete building that surrounds the RB and is divided into several structures. Examples of activities include: RAB excavation, assembly of pre-fabricated concrete floors, concrete pours, and installation of internal structures (including systems). This scope is judged to be reasonable.	The total duration assigned for construction of the RAB from the placement of basemat through the completion of connecting mechanical and electrical systems is approximately 36 months. RCW pipe fabrication activities that extend for 21 months are scheduled to commence 9 months preceding RAB construction. Based on engineering judgment and experience, this duration is considered reasonable.	In general, site preparation activities, module pre-fabrication activities precede RAB construction activities. In general, auxiliary system completion and turnover activities succeed RAB construction activities. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Turbine Building	Activities are included in the schedule for turbine building (TB) construction. Examples of activities include: excavation, installation of external and internal structures, and equipment assembly. This scope is judged to be reasonable.	The entire duration assigned for construction of the TB is approximately 34 months. The durations assigned for several of the activities are as follows: TB foundation, construction of external and internal structures, T/G table top – 24 months Placing and installing Process equipment/piping/HVAC – 24 months Condenser installation – 12 months Assemble T/G, install I&C and electrical systems – 13 months Based on engineering judgment and experience, this duration is considered reasonable.	In general, site preparation activities precede TB construction activities. Procurement and delivery of long-lead items (e.g., turbine generator and condenser etc.) are ongoing during TB construction activities, but complete prior to their installation. In general, turbine-generator system completion and turnover activities succeed TB construction activities. This logic is judged to be reasonable.
Radwaste Building	Activities are included in the schedule for the construction of the radioactive solid waste building. Examples of activities include: civil construction and mechanical and electrical installations. Note that liquid radioactive waste is stored in concrete storage tanks, and are located in the basement of the reactor auxiliary building. This scope is judged to be reasonable.	The duration assigned for the construction of the radioactive solid waste building is 5 months. This appears reasonable since the radwaste building only stores solid waste.	In general, site preparation activities precede radioactive solid waste building construction activities. In general, radioactive solid waste system completion and turnover activities succeed radioactive solid waste building construction activities. This logic is judged to be reasonable.
Diesel Generator Building	Activities are included in the schedule for diesel generator (DG) building construction. Examples of activities include: foundation preparation, assembly of concrete and steel structures, installation of DGs, and mechanical and electrical installations. This scope is judged to be reasonable.	The duration assigned for construction of the DG building is approximately 23 months. Note that this includes “relax” periods of 4 months between foundation preparation and installation of concrete structures and 3 months between installing DGs and performing mechanical and electrical activities. It is assumed that the labor force will be working in a more critical area during this period. Based on engineering judgment and experience, this duration is considered reasonable.	In general, site preparation activities precede DG building construction activities. In general, DG system completion and turnover activities succeed DG building construction activities. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Annex Building	Activities are included in the schedule for service building (SB) and maintenance building (MB) construction. Examples of activities include: excavation, assembly of pre-fabricated structures, and installation of equipment and piping, for each of the buildings. This scope is judged to be reasonable.	The duration assigned for construction of the SB and MB is approximately 24 months. Both buildings are constructed concurrently. Based on engineering judgment and experience, this duration is considered reasonable.	In general, site preparation activities precede SB and MB building construction activities. In general, MB system completion and turnover activities succeed MB construction activities. Subsequently, SB system completion and turnover activities succeed SB construction activities. This logic is judged to be reasonable.
Main Control Building	Activities are included in the schedule for the main control building (MCB) and secondary control building (SCB) construction. Examples of activities include: erecting concrete structures and pre-fabricated concrete slabs, and installation of equipment and ductwork. Installation of the design-built simulator building area is included in the scope. This scope is judged to be reasonable.	The duration assigned for the construction of each of the buildings is approximately: - Main control building = 25 months - Secondary control building = 25 months There is some overlap in duration between activities for each of these buildings. Based on engineering judgment and experience, this duration is considered reasonable.	In general, site preparation activities precede MCB and SCB construction activities. In general, MCB system completion and turnover activities succeed MCB construction activities, respectively. Subsequently, SCB system completion and turnover activities succeed SCB construction activities. This logic is judged to be reasonable.
Administration Building	Activities are not included in the schedule for the construction of the administration building. However, E.3-1 shows a generic ACR site layout that indicates a site location for the administration building is planned. The effort required to complete these buildings is not as significant as some of the other construction activities (e.g., the Reactor Building and Turbine Building), and it is unlikely that they would impact the critical path.	N/A	N/A

Activity	Scope	Duration	Logic
Circulating Water Building	Activities are included in the schedule for the construction of the condenser cooling water (CCW) main pump house, the raw service water (RSW) secondary pump house, and the CCW outlet structure. Examples of activities include: excavation, foundation, erecting external and internal concrete structures, installation of pumps, and mechanical and electrical installations. This scope is judged to be reasonable.	The duration assigned for the construction of each of the buildings is approximately: - CCW main pump house = 25mo. - RSW secondary pump house = 9 mo. - CCW outlet structure = 7mo. The RSW and CCW outlet structure are constructed during and prior to completion of the CCW main pump house. Based on engineering judgment and experience, this duration is considered reasonable.	In general, site preparation activities precede CCW pump house, RSW secondary pump house, and CCW outlet structure construction activities. In general, RSW and CCW outlet system completion and turnover activities succeed RSW and CCW outlet construction activities, respectively. Subsequently, CCW system completion and turnover activities succeed CCW construction activities. This logic is judged to be reasonable.
Transformers and Switchyard	Activities are included in the schedule for the construction of the main output transformer (MOT), unit service transformer (UST), and system service transformer (SST). Examples of activities include: pouring the foundation and installing the GIS. This scope is judged to be reasonable.	The duration assigned for transformer and switchyard construction is approximately 5 months. Based on engineering judgment and experience, this duration is considered reasonable.	In general, site preparation activities precede transformer and switchyard construction activities. In general, transformer and switchyard completion and turnover activities succeed the construction activities. This logic is judged to be reasonable.
	C. System Completion and Turnover[a]		
Transformers and Switchyard	Activities are included in the schedule for system completion and turnover of the main output transformer (MOT), unit service transformer (UST), and system service transformer (SST). Examples of activities include: verification, check, and testing of each of the systems. This scope is judged to be reasonable.	The duration assigned for transformer and switchyard system completion and turnover is approximately 1 month. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the preparation of the foundation and construction of the firewall for the MOT, UST, and SST precedes the transformer and switchyard completion and turnover. In general, the testing and commissioning of the transformers and switchyard succeeds the system completion and turnover of the transformers and switchyard. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Reactor Systems	Activities are included in the schedule for reactor system completion and turnover. Examples of activities include: verification, check, and testing of the Calandria, moderator, PHT system, etc. This scope is judged to be reasonable.	The duration assigned for reactor system completion and turnover is approximately 12 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the reactor system completion and turnover is preceded by the construction of the reactor building and systems. In general, the testing and commissioning of the reactor systems succeeds the reactor system completion and turnover. This logic is judged to be reasonable.
Safety Systems	Activities are included in the schedule for safety system completion and turnover. Examples of activities include: verification, check, and testing of the emergency coolant injection system, safe shutdown systems, etc. This scope is judged to be reasonable.	The duration assigned for safety system completion and turnover is approximately 12 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the safety system completion and turnover is preceded by the construction of the reactor building and systems. In general, the testing and commissioning of the safety systems succeeds the safety system completion and turnover. This logic is judged to be reasonable.
Turbine Generator Systems	Activities are included in the schedule for system completion and turnover of the turbine, generator, and auxiliaries. Examples of activities include: verification, check, and testing of each system component. This scope is judged to be reasonable.	The duration assigned for turbine generator system completion and turnover is approximately 10 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the turbine generator system completion and turnover is preceded by the construction of the turbine generator building. In general, the testing and commissioning of the turbine generator system succeeds the turbine generator system completion and turnover. This logic is judged to be reasonable.
Main Control Room Systems	Activities are included in the schedule for main control room system completion and turnover. Examples of activities include: verification, check, and testing of the main control building. This scope is judged to be reasonable.	The duration assigned for main control room system completion and turnover is approximately 1.5 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the main control room system completion and turnover is preceded by the construction of the main control room building. In general, the testing and commissioning of the main control room systems succeeds the main control room system completion and turnover. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Simulator[c]	An activity for the installation and commissioning of the simulator is included in the schedule. Although turnover is not specifically mentioned, it is assumed to be part of the installation and commissioning activity.	The duration assigned for simulator installation and commissioning is approximately three months. This duration appears to be reasonable.	In general, the simulator installation and commissioning is preceded by the construction of the simulator building and the manufacturing of the simulator. This logic is judged to be reasonable. The simulator installation and commissioning is succeeded by the development of the operator training program and the simulator software verification. This logic is evaluated in Table C-5.
Radwaste Systems	Activities are included in the schedule for radwaste system completion and turnover. Examples of activities include: verification, check and testing of the radioactive solid waste building, spent fuel bay purification and cooling system, and liquid radioactive waste system. This scope is judged to be reasonable.	The duration assigned for radwaste system completion and turnover is approximately 3 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the radwaste system completion and turnover is preceded by the construction of the radwaste building and the installation of the spent fuel bay and liquid waste management modules. In general, the testing and commissioning of the radwaste systems succeeds the completion and turnover of the radwaste systems. This logic is judged to be reasonable.
Electrical Systems	Activities are included in the schedule for electrical system completion and turnover. Examples of activities include: verification, check, and testing of the diesel generators. Appendix G of Reference 4.1 provides milestones for turnover activities of the station services secondary distributions systems and uninterruptible power supply systems. However, detailed activities are not included in the schedule. This scope is judged to be reasonable.	The duration assigned for system completion and turnover of the diesel generators is approximately 1 month. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants. The durations for the station services secondary distributions systems and uninterruptible power supply systems are unknown because only milestones are provided.	In general, the diesel generator building construction precedes the diesel generator completion and turnover. In general, the testing and commissioning of the diesel generator succeeds the diesel generator completion and turnover. Additionally, the commissioning activities for the station services secondary distributions systems and uninterruptible power supply systems are preceded by the turnover milestones for these systems. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Water Treatment Systems	Activities are included in the schedule for water treatment system completion and turnover. Examples of activities include: verification, check, and testing of the water treatment plant. This scope is judged to be reasonable.	The duration assigned for water treatment system completion and turnover is approximately 1 month. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the water treatment plant construction precedes the water treatment system completion and turnover. In general, the testing and commissioning of the water treatment system succeeds the water treatment completion and turnover. This logic is judged to be reasonable.
Other Plant Systems	Activities are included in the schedule for the completion and turnover of other plant systems. Examples include: verification, check, and testing of demineralized water storage, liquid nitrogen storage, sewage treatment plant, fire pump station, filtered water storage, hazardous chemical storage, etc. This scope is judged to be reasonable.	The duration assigned for system completion and turnover for each of the other plant systems is approximately 1 month each. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, construction precedes system completion and turnover for each of the other plant systems. In general, testing and commissioning succeeds the system completion and turnover for each of the other plant systems. This logic is judged to be reasonable.

References and Notes:

a. This schedule is provided in Appendix F of Reference 4.1.
b. A single schedule activity is provided for site preparation that extends for 6 months. The schedule is not specific regarding key activities (e.g., soil preparation, laydown area preparation, etc.), although Section 2.2.1.7 of Reference 4.1 outlines a partial list of construction facilities that need to be considered when developing the site. This issue is discussed in more detail in Section 3.3 of this appendix.
c. This schedule is provided in Reference 4.4.

Table C-5. AECL ACR-700 Schedule Evaluation
Start-up and Commissioning Phase

Activity	Scope	Duration	Logic
A. System Testing and Qualification[a]			
Transformers and Switchyard	Activities are included in the schedule for the testing and commissioning of the transformers and switchyard. Examples of activities include pre-service inspections, performance test of the transformers, and transfer tests. This scope is judged to be reasonable.	The duration assigned for the testing and commissioning of the transformers and switchyard is approximately 3 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the commissioning of the transformers and switchyard is preceded by the construction turnover of the main output and station service transformers. This logic is judged to be reasonable. In general, the commissioning of the transformers and switchyard is completed prior to fuel load. This logic is judged to be reasonable.
Reactor Systems	Activities are included in the schedule for the testing and commissioning of the reactor systems. Examples of activities include Calandria internal inspections, Calandria leak tests, and moderator circuit leak tests. This scope is judged to be reasonable.	The duration assigned for the testing and commissioning of the reactor systems is approximately 15 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the commissioning of the reactor systems is preceded by the construction turnover of the Calandria and moderator systems. This logic is judged to be reasonable. In general, the commissioning of the reactor systems is completed prior to fuel load. This logic is judged to be reasonable.
Safety Systems	Activities are included in the schedule for the testing and commissioning of the safety systems. Examples of activities include Emergency Coolant Injection dynamic testing, pressure testing of tanks, and functional tests of the safe shutdown systems. This scope is judged to be reasonable.	The duration assigned for the testing and commissioning of the safety systems is approximately 12 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the commissioning of the reactor systems is preceded by the construction turnover of the safe shutdown and the emergency coolant injection systems. This logic is judged to be reasonable. In general, the commissioning of the safety systems is completed prior to fuel load. This logic is judged to be reasonable.
Turbine Generator Systems	Activities are included in the schedule for the testing and commissioning of the turbine generator systems. Examples of activities include EHC logic checks, generator leak test, and lube oil operational checks. This scope is judged to be reasonable.	The duration assigned for the testing and commissioning of the turbine generator systems is approximately 12 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the commissioning of the turbine generator systems is preceded by the construction turnover of the system. The majority of the turbine generator system commissioning activities are complete prior to fuel load. The exception is for the EHC commissioning activities which complete shortly after fuel load and before final commissioning. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Main Control Room Systems	Activities are included in the schedule for the testing and commissioning of the main control room systems. Examples of activities include pre-operation and logic checks of plant controls, main control room panel inspections, and software operational checks. This scope is judged to be reasonable.	The duration assigned for the testing and commissioning of the main control room systems is approximately 12 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the commissioning of the main control room systems is preceded by the construction turnover of the main control room building. This logic is judged to be reasonable. In general, the commissioning of the main control room systems is completed prior to fuel load. This logic is judged to be reasonable.
Simulator[b]	An activity for the installation and commissioning of the simulator is included in the schedule. The schedule also includes an activity for the software verification of the simulator.	The duration assigned for the installation and commissioning of the simulator is 3 months. This duration is judged to be reasonable. The duration assigned for the simulator software verification is 6 months. This duration is highly dependent on the number of errors that are identified (and subsequently fixed) during the verification stage. This duration is expected to be sufficient assuming the number of errors is small.	Simulator installation and commissioning is preceded by the manufacturing of the simulator and the construction of the simulator building. This logic is judged to be reasonable. Simulator software verification is conducted on-site and preceded by simulator installation and commissioning. This represents a deviation from what has been done in the U.S. Simulator software verification has generally been completed at the vendor's location before the simulator is shipped to the site. This logic has been preferred because it allows the vendor complete access to the simulator to correct any errors that are identified during software verification. Once on site, the vendor may not have the access needed to efficiently correct errors. The simulator software verification process could be extended as a result. The logic that AECL has provided (i.e., software verification being conducted on-site) was chosen to allow the training program to be prepared in parallel with software verification activities. This was done to prevent simulator development and training activities from affecting the critical path. This logic may be appropriate if the simulator vendor is able to establish a high level of confidence that minimal errors will be identified during the software verification process. Otherwise, there is a risk that simulator development and training could impact the critical path as there is only 1 month of float associated with these activities.

Activity	Scope	Duration	Logic
Radwaste Systems	Activities are included in the schedule for the testing and commissioning of the radwaste systems. Examples of activities include spent resin transfer tests, spent fuel transfer tests, spent fuel bay leak tests, and decontamination performance tests. This scope is judged to be reasonable.	The duration assigned for the testing and commissioning of the radwaste systems is approximately 9 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the commissioning of the radwaste systems is preceded by the construction turnover of the resin transfer, spent fuel transfer, spent fuel bay, and the liquid radioactive waste management systems. This logic is judged to be reasonable. In general, the commissioning of the radwaste systems is completed prior to fuel load. This logic is judged to be reasonable.
Electrical Systems	Activities are included in the schedule for the testing and commissioning of the electrical systems. Examples of activities include diesel generator synchronization and load tests, MCC inspections and testing, and uninterruptible power supply performance tests. This scope is judged to be reasonable.	The duration assigned for the testing and commissioning of the electrical systems is approximately 18 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the commissioning of the electrical systems is preceded by the construction turnover of the diesel generator building, distribution systems, and uninterruptible power system. This logic is judged to be reasonable. In general, the commissioning of the electrical systems is completed prior to fuel load. This logic is judged to be reasonable.
Water Treatment Systems	Activities are included in the schedule for the testing and commissioning of the water treatment systems. Examples of activities include pre-operational inspections, water flow tests, and water quality tests. This scope is judged to be reasonable.	The duration assigned for the testing and commissioning of the water treatment systems is approximately 3 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the commissioning of the water treatment systems is preceded by the construction turnover of the water treatment plant. This logic is judged to be reasonable. In general, the commissioning of the water treatment systems is completed prior to fuel load. This logic is judged to be reasonable.
Other Plant Systems	Activities are included in the schedule for the testing and commissioning of other plant systems. Examples of activities include the testing of the main condenser, sewage treatment plant, and the auxiliary boilers. This scope is judged to be reasonable.	The duration assigned for the testing and commissioning of the balance of plant systems is approximately 9 months. This duration appears to be consistent with what was achieved at Qinshan and previous U.S. plants.	In general, the commissioning of the other systems is preceded by their construction turnover. This logic is judged to be reasonable. In general, the commissioning of the other plant systems is completed prior to fuel load. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
B. Fuel Loading[a]			
Fuel Loading	Activities are included in the schedule for loading the fuel. For the purpose of this schedule review, fuel load is considered to be complete when the first criticality is achieved. This scope is judged to be reasonable.	The duration assigned for the loading of the fuel is approximately 4 months. This is consistent with the duration achieved at Qinshan (see Table C-1) and is judged to be reasonable.	Fuel loading is preceded by the initial commissioning of the primary heat transport system (the remaining commissioning activities require that the fuel be loaded) and the commissioning of the fuel transfer system. This logic is judged to be reasonable.
C. Final Commissioning[a]			
Final Commissioning	Activities are included in the schedule for the final commissioning of the plant. The plant is taken to full power and, on the way up, an integrated test of the plant is conducted. A warranty test is then performed, at the completion of which the plant is declared in-service.	The duration assigned for the final commissioning of the plant is approximately 4 months. The duration achieved during the final commissioning of the Qinshan plant was 2 months (see Table C-1). Although AECL does not provide rationale, this extra time may have been added to allow for design issues that are unique to the ACR-700 (as compared to the CANDU 6) or for regulatory reviews. This is judged to be reasonable.	The final commissioning of the plant is preceded by fuel loading and all building/system commissioning activities. This represents the final stage of the construction process and consequently has no successors. This logic is judged to be reasonable.

References and Notes:

a. This schedule is provided in Appendix G of Reference 4.1.
b. This schedule is provided in Reference 4.4.

Table C-6. AECL ACR-700 Schedule Evaluation
Training Phase

Activity	Scope	Duration	Logic
A. Operator Training[a]			
Operator Training	The schedule includes activities for the recruitment of a training staff, training program development, and operator training. Operator training on the simulator is not differentiated from non-simulator training. This scope is judged to be reasonable.	The durations assigned for operator training activities are as follows: - Recruit Train. Staff = 6 mo - Prep. Train. Prog. = 12 mo - Operator Training = 16 mo The schedule accommodates the NRC requirement that the operating training program must start a minimum of 18 months before fuel load.	In general, training activities are preceded by the commissioning and software verification of the simulator. Training activities are succeeded by Fuel Load. This logic is judged to be reasonable.
B. Operator Training on Simulator[a]			
Operator Training on Simulator	As stated above, operator training on the simulator is not differentiated from non-simulator training.	N/A	N/A

References and Notes:

a. This schedule is provided in Reference 4.4.

Table C-7. AECL ACR-700 Schedule Evaluation
Licensing and ITAAC Phase

Activity	Scope	Duration	Logic
A. Pre-Fuel Load[a]			
Engineering Reviews	N/A	N/A	N/A
Module Shop Inspections	N/A	N/A	N/A
On-site Construction Inspections	N/A	N/A	N/A
Testing and Qualification Reviews	N/A	N/A	N/A
B. Post-Fuel Load[a]			
Engineering Reviews	N/A	N/A	N/A
On-site Construction Inspections	N/A	N/A	N/A

References and Notes:

a. The schedule provided in Reference 4.3 includes a single activity for ITAAC. This issue is discussed in more detail in Section 3.6 of this appendix.

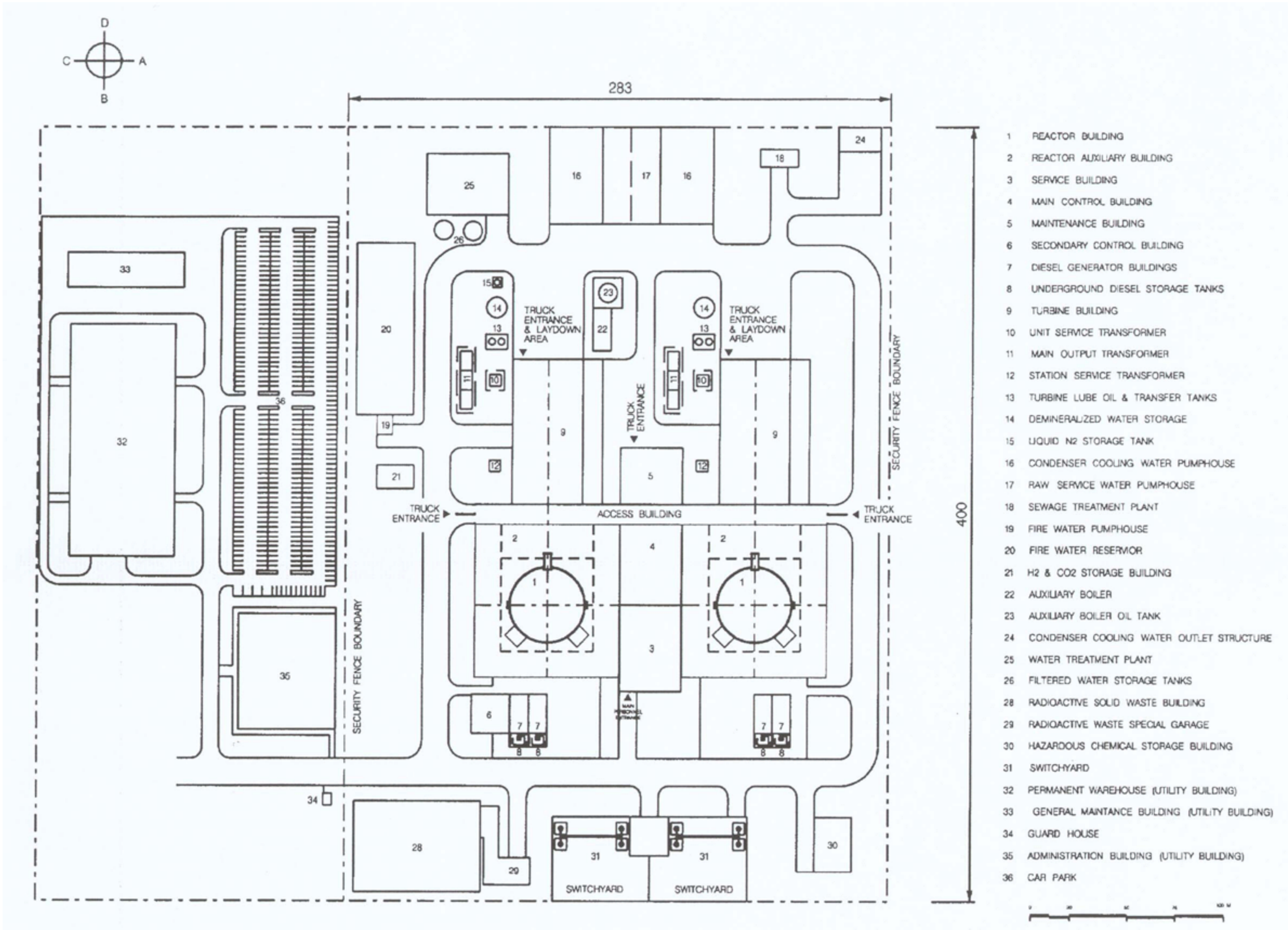

Figure C-4. ACR-700 Plot Plan

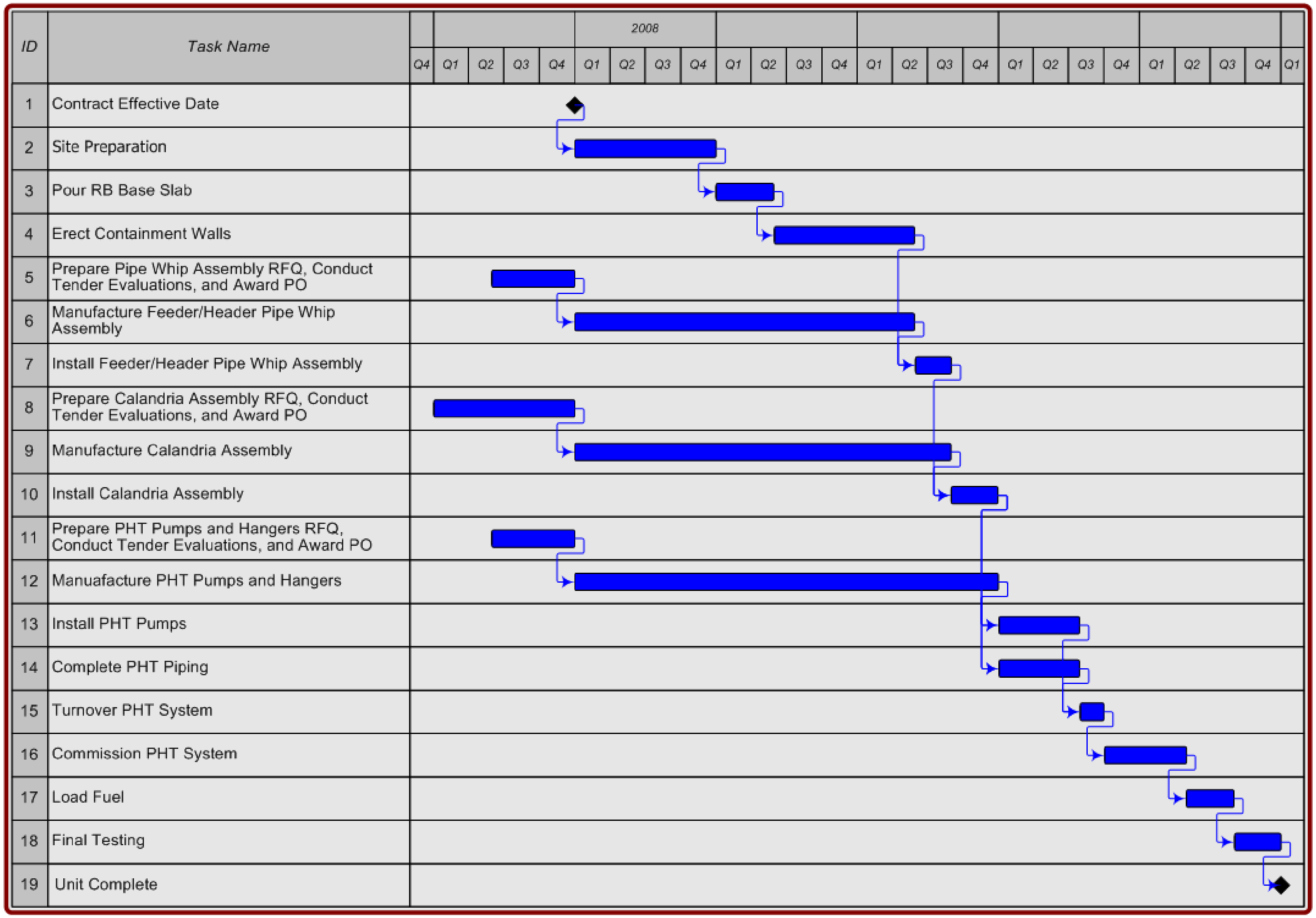

Figure C-5. ACR-700 Critical Path

D

Westinghouse AP1000

1. Background

The AP600 is a passive pressurized water reactor power plant designed by an international team headed by Westinghouse in cooperation with the U.S. Department of Energy (DOE) and Advanced Reactor Corporation (ARC). Upon completion of the AP600 design, and near the time that the plant achieved Design Certification (DC) from the Nuclear Regulatory Commission (NRC) in 1999, Westinghouse determined that the plant would not be able to meet the market requirements for plant cost. Therefore, they undertook a project to develop the AP1000, which is a larger, higher power version of the original plant.

To understand most aspects of the AP1000 project, it is necessary to understand the conclusions that were reached during the AP600 development, and then apply the incremental changes that were necessary to design the AP1000. For example, a large amount of design and FOAKE work had been completed on the AP600 at the initiation of the AP1000 project; therefore, all aspects of the plant design that could remain unchanged are preserved in the AP1000 design. Additional design work that was necessary to support the application for DC for the AP1000 has been completed. However, there are a number of areas where a significant design effort remains before an AP1000 could be built.

AP1000, like AP600, was designed with the goal of meeting the standards set by the utilities, EPRI, and DOE in the Advanced Light Water Reactor (ALWR) Utility Requirements Document (URD). The Construction Plan and Schedule Report, Reference 5.2, developed as a FOAKE task for the AP600 was used as the basis for the current AP1000 schedule. Specifically, the integrated project schedule for the AP1000 is an update of the AP600 schedule. Very few changes were required because, while some module and component sizes have changed, the number and duration of individual installation activities has remained virtually the same within the nuclear island. The current schedule is a detailed Level 3 Primavera schedule for an NOAK AP1000 plant. References 5.3, 5.4, 5.5, and 5.6 incorporate the information extracted from the integrated schedule.

Westinghouse refers to the AP1000 schedule as a ‘4D’ schedule. This refers to the schedule information being integrated with a 3-dimensional model of the plant components, such that planners may visualize the activities within the schedule as they are taking place. Reference 5.8 describes the 4D schedule in greater depth.

1.1. Plot Plan

To orient the reader to the layout of the Westinghouse AP1000, a plot plan and building arrangement sketch from Reference 5.7 are provided as Figures D-2 and D-3, respectively.

1.2. Systems and Equipment

The major systems and equipment of the Westinghouse AP1000 are organized by building and provided below.

Nuclear Island (Containment and Auxiliary Buildings)

- Reactor System
- Reactor Coolant System
- Steam Generator System
- Normal Residual Heat Removal System
- Passive Core Cooling System
- Passive Containment Cooling System
- Chemical and Volume Control System
- Steam Generator Blowdown System
- Diverse Actuation System
- Plant Control System
- Plant Protection and Safety System
- Incore Instrumentation System
- Radiation Monitoring System
- Class 1E DC and UPS
- Non-Class 1E DC and UPS Systems
- Data Display and Processing System
- Fuel Handling and Refueling
- Primary Sampling System
- Secondary Sampling System
- Special Monitoring System
- Seismic Monitoring System
- Radioactive Controlled Area Ventilation
- Nuclear Island Non-Radioactive Vent System
- Annex and Auxiliary Building Non-Radioactive Vent Systems
- Containment Recirculation Cooling System
- Containment Air Filtration System
- Health Physics and Hot Monitoring
- Containment Hydrogen Control System
- Containment Leak Rate Test System
- Central Chilled Water system
- Spent Fuel Pool Cooling System
- Component Cooling Water System
- Material Handling and Transfer System

Turbine Building

- Main Turbine System
- Main Steam System
- Main Generation System
- Turbine Control and Diagnosis
- Turbine Vent, Drains, and Relief Valves
- Turbine Building Closed Cooling System
- Condensate System
- Condenser Tube Cleaning System
- Condenser Air Removal System
- Condensate Polishing System
- Circulating Water System
- Demineralized Water Treatment
- Demineralized Water Transfer and Storage System
- Main and Startup Feedwater System
- Gland Seal System
- Generator Hydrogen and Carbon Dioxide Systems
- Heater Drain Systems
- Hydrogen Seal Oil System
- Lube Oil System
- Turbine Building Ventilation

Radwaste Building

- Gaseous Radwaste System
- Liquid Radwaste System
- Solid Radwaste System
- Radwaste Building HVAC

Diesel Generator Building

- On-site Standby Power System
- Standby Diesel and Auxiliary Boiler Oil System
- Diesel Generator Building Heating and Ventilation System

Other

- Main AC Power System
- Transmission Switchyard and Off-site
- Service Water System
- Fire Protection System
- Auxiliary Steam Supply System
- Compressed Instrument Air System
- Chemical Feed System
- Communication System
- Grounding and Lighting
- Heat Tracing
- Plant Lighting
- Meteorological Monitoring System
- Plant Gas System
- Potable Water System
- Hot Water Heating System
- Wastewater System
- Sanitary Drain System

2. Schedule Assumptions

Westinghouse established several assumptions that influence schedule duration and construction planning.

2.1. Fundamental Project Assumptions

1. The AP1000 schedule is for the NOAK plant built in the U.S. The learning curve is accelerated and design problems are for the most part resolved prior to work start.
2. Work hours allow for make-up days during the construction period. The schedule is based on 5 days/10 hours per day with some second shift activities for extended concrete pours, etc.
3. Key vendor working relationships have been established for the major equipment. Drawing approval has either occurred or is scheduled and is not significant. All working procedures are assumed to be in place.
4. Labor assignments have all been negotiated and agreed upon prior to construction start, with no strikes or major labor delays assumed.
5. Cash flow that is accelerated by extensive modularization will not be restricted. If this is true, it will result in on-time plant start up and shorter loan durations, which will make up for the early expenditure.

2.2. Licensing and Permitting Assumptions

6. A stable nuclear regulatory environment is assumed.
7. 100% certified plant design is assumed to be available prior to the start of the licensing process and only site-specific details would need to be reviewed in detail.

8. Local permitting and codes are assumed to be within normal limitations. There are no allowances made to anticipate special drainage, erosion control, or any other local jurisdiction requirements.
9. NRC, ACRS, and public review periods are estimated using EPRI and USG input.

2.3. Site-Specific Assumptions

10. It is assumed that the site has been selected and dollars are available for the environmental, seismic, soils, and hydrology investigations.
11. The reference site for the construction is Kenosha, Wisconsin.
12. Site is assumed to have highway access within 1 mile and rail access within 5 miles or less.
13. It is assumed that there is an ample supply of skilled craftsmen to completely support the project schedule including off-shift work, overtime work, or holiday work.
14. On-site parking and change facilities are assumed available.
15. Reasonable weather protection assumed to be provided locally so that work can continue year round.
16. Site is assumed to be clear and level with no special problems.
17. Seismic Zone 1, all design and construction techniques that are assumed have been incorporated.
18. While within one mile of Lake Michigan, no cooling is assumed to be available from the lake; a hyperbolic, natural draft cooling tower is assumed.
19. The majority of yard construction is assumed to occur between licensing and first concrete to minimize the impact on major construction activities.
20. Raw materials such as sand, gravel, fill, and topsoil are assumed to be in plentiful supply within a reasonable trucking distance. Ample space for limited storage for these materials will be provided on-site.

2.4. Construction Assumptions

21. In-containment installation sequence is based on two four-man crews to rig and set modules. In general, each module is estimated as a two-day evolution to stage, rig, and set the module/equipment. Because of work congestion, most modules will need to be installed in series.
22. AP1000 has approximately 600 modules, which contain piping and other mechanical and electrical components. In addition, approximately 900 piping assemblies are included in the design. All major pipe areas are modularized. Large modules will carry 90% of the pipe, valves, and instruments in the containment systems.

2.5. Engineering and Procurement Assumptions

23. All engineering is assumed to be complete and specifications and bid documents are prepared in a computerized database available from previous plant projects.
24. A 30-day float time is built into all procurement activities. Major equipment lead times were quoted during the cost research by proposed nuclear vendors. Remaining lead times were estimated and will need to be confirmed during final design.
25. No pre-award vendor quality audits have to be performed to get any supplier on the ASL.
26. All shipping, handling, and preventative maintenance criteria have been established. All hold points are known and scheduled.
27. Procurement documents to support early yard construction is assumed to be prepared ahead of licensing completion with contracts and purchase orders being issued immediately following project release.
28. Long-lead equipment is assumed to be ordered before issue of the COL using limited fund commitments.
29. There are no available marine docking facilities.
30. Truck and train are the primary assumed methods of transportation to the construction site. All bridges and roadways are assumed to be capable of handling large and heavy loads.

3. DETAILED SCHEDULE EVALUATION

A detailed evaluation was performed using the approach described in Section 1.4.2 on the following phases of the AP1000 schedule: Engineering, Procurement, Construction, Start-up and Commissioning, Training, and Post-COL Licensing and ITAAC. The results of the detailed evaluation are provided in Tables D-3 through D-8 and summarized below.

3.1. Engineering

Scope

Westinghouse assumes that all detailed engineering is 100% complete for the NOAK plant with the exception of the site-specific engineering. Additionally, they assume that all COL application engineering packages, that are not site specific, have been completed and pre-approved as a result of earlier COL applications. Therefore, the preliminary and detailed engineering schedule provided focuses on a number of pre-COL and post-COL activities. Some activities specifically support the site-specific COL licensing effort, while others are more strictly site-specific construction details.

In general, the scope of the engineering schedule for the AP1000 appears to be complete and appropriate.

Details of simulator and module design are not provided in the schedule, presumably because these would have been complete from previous plants. The omission of detailed design information for modules is appropriate for the NOAK plant schedule. However, the potential impact of the lack of simulator design activities is discussed in Section 3.3 of the report.

Duration
The total duration for the preliminary engineering activities that support the COL application and detailed engineering following the approval of the application is approximately 25 months. This duration appears to be aggressive yet reasonable for the number and type of tasks that are to be completed for the NOAK plant. Additionally, time could be made up by augmenting the engineering staff in the event that engineering activities fall behind schedule.

Logic
The logic within the AP1000 engineering schedule is initiated by the selection of the plant site. However, the schedule is actually driven by planning backwards from initial construction activities and the need for the COL approval prior to first concrete. Successors to the engineering schedule include the COL licensing activities as well as the start of some procurement activities. This logic is judged to be reasonable.

No predecessor task is provided for the Selection of Meteorological Tower Location, and this is scheduled to occur prior to site selection. This activity appears to have minimal impact on the rest of the schedule, and so is of limited concern.

3.2. Procurement

Scope
The detailed procurement schedule (almost 2000 activities) appears to include activities for all major plant equipment and modules. The procurement scope does not identify the general procurement of bulk commodities such as concrete, structural steel, conduit, and wiring. However, in Section 4.3.4 of Reference 5.2, Westinghouse notes that bulk material procurements for modules, such as steel, cable, and pipe, shall be specified and procured by the module subcontractor/fabricator. Bulk commodity procurements to support each module fabrication activity are identified within the schedule.

As noted earlier in this appendix, the procurements schedule assumes that engineering to support procurements is 100% complete. In addition, all major suppliers have been identified and approved, all shipping and handling requirements have been established, and key equipment has been scheduled with enough float so that inspections and minor repairs, if necessary, can be supported. It is also assumed that all inspection hold points are known and have been scheduled.

In general, each procurement includes three activities, namely, a bid, evaluate, and award (BEA) activity; a procure module component and commodity activity; and a module delivery activity. Modules include an additional activity for the procurement of materials. For mechanical modules, this activity has two parts: a “procure pipe, valves, electrical” and “procure various commodities” activities.

Inspection activities are not explicitly included within the schedule, however, Westinghouse describes in Reference 5.2 that “all safety/code equipment and modules are to be inspected, tested, and stamped at the vendor shop with final flush and hydro-testing complete and insulation installed to a point just clear of field weld points."

The procurement scope is considered reasonably complete for this stage of project development. A schedule that is more detailed with respect to bulk procurements, testing requirements, and delivery will need to be developed to support a plant construction contract once initial vendor relationships are established.

Duration

Durations for the BEA, commodity procurements, fabrication, and delivery activities within the procurement schedule are considered appropriate for an NOAK plant. Westinghouse indicates that the procurement durations are based upon actual quotes for major equipment and representative modules. The durations provided by vendors were used for the fabrication portion of the procurement schedule with additional time being given for BEA and delivery. Durations for the more minor procurements were estimated by Morrison Knudson (MK).

There are approximately 20 electrical and other procurement activities within the schedule that have a one-day duration and tie directly to their respective construction activities without the typical BEA, procure, and deliver activities. It is presumed that these are recent additions to the schedule that have not yet been well defined. Normal procurement schedule development is expected to correct these minor issues.

The long-lead procurement of the reactor vessel and head within the schedule does not reflect the latest Westinghouse plans for this long-lead item. If the owner desires, the reactor vessel and head may be pressure tested separately. This change would allow the reactor vessel to be released for manufacture just six months prior to the start of site preparation instead of the current schedule's nine months.

The durations provided in the schedule for procurements are judged to be reasonable.

Logic

The placement of procurement activities within the overall schedule assumes that procurements are not critical. That is, all procurement activities are linked from the finish date of the delivery to the construction activity that installs that equipment or module with 30 days of built-in float. In general, there are no predecessors for BEA activities, with the exception of the long-lead items. Delivery activities typically have successors tied to construction activities. This logic is considered reasonable and well developed.

3.3. Construction

Scope

The AP1000 documentation clearly defines the scope of work (buildings, equipment, and systems) required to construct an AP1000. Scope definition is completely provided for the Nuclear Island (Containment, Shield Building, and Auxiliary Building), Annex Building, Turbine Building, Radwaste Building, and Diesel Generator Building. Westinghouse has a mostly complete design for this scope of work for the AP600/AP1000. A detailed material list and cost estimate has been prepared for this work and was used as an additional reference in the schedule evaluation (Reference 5.1).

Little or no information has been provided on the site-specific portions of the plant, namely the Administration Building, Warehouses, Maintenance & Paint Shop, Cooling Tower, Switchyard, and Transformer Area. The details of these areas are to be negotiated with the eventual plant owner, and thus are only minimally addressed. Note that the schedule does not include details on the construction of a simulator.

We note that important construction activities take place during the site preparation period. These activities are logical and necessary to support rapid plant construction that starts with pouring the nuclear island basemat. These site preparation period activities include placing working basemats, fabricating rebar modules, placing basemat rebar modules, and the on-site fabrication of the containment vessel's bottom head.

System completion and turnover activities have been developed by building area and discipline, therefore, verification of complete scope was difficult to perform. In general, these consist of piping integrity checks and electrical checks. Other tests, such as hydro tests, were reviewed in the Start-up and Commissioning section, consistent with the Westinghouse designation.

Duration

AP1000 construction durations for each schedule activity were established by MK during the AP600 schedule preparation. These durations have been reviewed by schedule design review teams that included construction experts from utilities, constructors, DOE, ARC, EPRI, and Westinghouse. Comments from the schedule design review teams were considered and resolved.

Construction starts with 18 months of site preparation, mobilization, and early construction activities. The numerous temporary and permanent buildings constructed during the site preparation period are shown as single activities. For example, the Class C Warehouse construction is scheduled to take approximately two months (9 weeks). While this is possible, this schedule would require tight coordination of construction activities (excavation foundation, place foundation, erect structure, erect roof, walls, and doors, construct offices/bathrooms, install electrical/lighting, install fire protection system, and install storage shelves). Future site preparation schedules would need to further develop the planned building construction activities and other site-preparation activities.

Site preparations of permanent structures include grading and excavation activities. The schedule includes 4.5 months to prepare the 40-foot-deep nuclear island excavation and 3 months to install drains, sumps, a working slab, and rebar for the nuclear island basemat. These durations are considered reasonable.

Note that the AP1000 nuclear island schedule has been resource loaded with concrete quantities which allowed a somewhat more detailed evaluation of the durations for concrete pours. Plant construction starts with a 2-day (30-hour) continuous pour of the nuclear island basemat with about 7,000 cubic yards of concrete poured using four concrete pumps. This is considered reasonable if the on-site concrete batch plant and transit trucks have the capacity to deliver the concrete. There are currently 142 concrete placement activities in the nuclear island that place approximately 50,000 cubic yards of concrete. This translates into approximately 250 cubic yards/day of concrete poured over 200 days. These durations are considered to be reasonable.

Based on quantity information within Reference 5.1, the overall estimated quantities of concrete for each of the major building were compared with the overall construction durations. This information is summarized in Table D-1. A review of this information reveals no major obstacles to achieving the construction within the durations provided.

Table D-1. Westinghouse AP1000 Concrete Quantities and Building Construction Duration

Area	Approx. Concrete (Cubic Yards)	Total Duration
Yard	500	
Nuclear Island Basemat Pour	7,000	2 days
Shield Building	30,000	27 months
Auxiliary Building	14,000	27 months
Subtotal Nuclear Island	**52,000**	
Turbine Building	14,000	24 months
Annex Building	5,000	17 months
Radwaste Building	1,000	11 months
Diesel Generator Building	500	10 months
Total Concrete	**72,000**	

Note that the setting of modules typically takes 2 days within the schedule. 18 working days are planned to set the plant's two steam generators, and 20 working days are planned for setting the plant's reactor vessel. These durations are judged to be reasonable.

Durations for completing and turning over systems are typically of short duration immediately following installation activities. These durations are reasonable.

Based on our experience with the fast-track construction of fossil power plants and plant systems, we consider the overall durations for the installation of plant buildings and associated systems to be aggressive, yet reasonable, for the NOAK. The building construction durations that will be required to meet the 36-month schedule (from first concrete to fuel load) should be achievable given the assumptions made.

Logic

The predecessor and successor logic provided for the site-preparation phase is reasonable. Underground utilities are installed early in the site preparation process to allow the completion of plant roads, crane access areas, and other activities.

Plant construction schedules have been prepared for all major buildings. Open-top construction using a heavy-lift crane is planned for the reactor and the turbine buildings. In general, floor placements are completed before interconnection and start-up/commissioning activities are initiated, especially within the reactor building. However, the turbine building construction will also make use of side entry to the building for the installation of some major equipment after the structure is partially completed. Temporary enclosures are planned to provide weather protection and ensure construction progress is not delayed by weather. Building-to-building relationships are also considered and planned into the schedule logic. The overall predecessor and successor logic provided in the construction schedule is reasonable. For additional construction logic information, reference the critical path discussion provided in Section 5 of this appendix.

3.4. Start-up and Commissioning

Scope

The start-up and commissioning activities scheduled for the majority of the AP1000 systems involving piping are hydro and flush, electrical and logic checkouts, instrument calibration, and pre-operational testing to verify system performance. Typical startup activities for electrical and main control room systems include final installation and setup of instrumentation and testing to verify proper system operation. This scope of start-up and commissioning activities is judged to be reasonable. However, for the AP1000 systems listed below, the only start-up and commissioning activity included in the schedule is "system startup," the duration of which is typically less than ten days. Specific startup activities are not detailed.

- Auxiliary Steam Supply System (ASS)
- Hydrogen Seal Oil System (HSS)
- Heater Drain System (HDS)
- Main Turbine System (MTS)
- Condenser and Air Removal System (CMS)
- Main Generation System (ZAS)
- Turbine Island Vents, Drains, and Relief System (TDS)
- Secondary Sampling System (SSS)
- Turbine Building Ventilation System (VTS)

In addition, the following systems are omitted from the start-up and commissioning section of the AP1000 schedule.

- Transmission Switchyard and Off-site Power System (ZBS)
- Containment System (CNS)
- Radiation Monitoring System (RMS)
- Main Turbine Control and Diagnostics System (TOS)
- Data Display and Processing System (DDS)
- Excitation and Voltage Regulation System (ZVS)
- Demineralized Water Treatment System (DTS)

Unless the activities required to start-up and commission the systems in the two bulleted lists are covered by start-up and commissioning activities for other systems, the scope of the AP1000 schedule with respect to start-up and commissioning is not complete.

Duration

Individual start-up and commissioning activities range in duration from 1 working day for tasks such as verification of system performance and termination of cables, to 20-25 working days for hydro of system piping. The actual duration of all start-up and commissioning activities for a system is typically several months to approximately one year, and is dependent upon the completion of construction and other start-up and commissioning activities. For example, hydro and flush of a system's piping may be completed, but the next set of start-up and commissioning activities, such as testing and verification of the system's performance, may not start for several months because predecessor construction activities are not yet completed. In general, the durations of start-up and commissioning activities appear to be reasonable.

Logic

In general, the scheduling of start-up and commissioning activities is logical. Hydro of system piping is scheduled after the completion of the associated piping system and appropriate piping integrity checks. Electrical checkouts are scheduled after connection of power to system components, and logic checkouts are scheduled after installation of DPUs. System testing and verification is scheduled after the completion of appropriate construction tasks and/or after verification of proper supporting system performance. Start-up and commissioning of electrical and main control room systems is appropriately scheduled after completion of component installation and setup and proper electrical connections. In general, all start-up and commissioning activities are scheduled to occur before fuel load.

Fuel load itself is scheduled after the completion of containment vessel ILRT and SIT and after tech spec surveillance test open items are closed. After fuel load, tech spec surveillance for initial criticality is scheduled, followed by power ascension testing. Two final activities are scheduled near the start of power ascension testing: final adjustment of the pressurizer spray valves, and final calibration of the special monitoring system. The durations of these activities are one and two days, respectively.

3.5. Training

There are only two training activities within the AP1000 schedule. These include, "Operator Training" and "Operator Training on Simulator." This definition provides minimal information on the details of the many activities that must be included within operator training. Thirty months of operator training and 11 months of simulator training are planned with operator training starting in site preparation month 13 and simulator training starting in plant construction month 15. Operator training starts after the Phase I Administration Offices are complete and this training is scheduled to be finished before pressurizing for the cold hydro. Simulator training starts after the Phase II Administration Offices are complete but the plant construction scope does not include details for a simulator. The simulator training is scheduled to be finished before the Hot Function Test.

Additional definition of training activities will be required prior to plant construction. Discussions with Westinghouse personnel indicate that operator training and simulator training is considered to be an activity that will be an owner responsibility and will be negotiated with the owner prior to commitment to build.

The operator training schedule should also be reviewed to identify training activities that will be required to allow operator support for start-up and commissioning activities that start in construction month 9.

Refer to Section 3.3 of this report for a discussion of the general impacts of training on plant construction schedules.

3.6. Post-COL Licensing and ITAAC

Scope

There are 68 licensing activities included in the AP1000 schedule that begin following the issue of COL. These activities include the following types of activities. See Table D-8 for an additional listing.

- Technical analyses such as “Pipe Break Hazards Analysis”,
- As-built documentation preparation,
- Operability testing,
- Development of inspection programs,
- Operations, monitoring, and testing procedure development,
- Security Plans,
- Human Factors Engineering,
- Issuing of Federal Register Notice for Fuel Load,
- Responding to Generic Letters and Bulletins, and
- Quality Assurance for Operators.

It is not clear from the activity titles whether these activities are considered to be required ITAAC activities. However, it does appear that some activities are vendor activities and others are NRC review periods. Additionally, there are two activities within the schedule that are specifically identified as ITAAC. These include:

- ITAAC 3.3.11 – Concrete Over Soft Soil @ 84
- ITAAC 3.3.11 – Concrete Over Soft Soil @ 117’-6”

The scope identified for post-COL licensing and ITAAC activities are developed to a greater extent than any other plant schedule. The identification of these activities is critical to the ability to start up the plant in a timely manner.

Additional definition of the licensing, inspection, and ITAAC activities will be required; however, the scope is well defined for this phase of development.

Duration

The duration of the post-COL licensing and ITAAC activities varies from 1 to 400 days. The activities with longer durations, ranging from about 60 to 400 days, appear to be program development and analysis activities. The shorter durations, typically 5 to 40 days, include testing, review, and issuing of the Federal Register Notice.

For the NOAK schedule, the durations that are presented appear to be reasonable; however, the scope is not understood or developed to a level of detail to allow for additional verification.

Logic

The post-COL licensing and ITAAC activities are generally preceded by engineering and licensing activities in support of the COL application; however, there is no restraint on the early start of many of these activities other than the establishment of the team for plant construction. The restraint on about half of the activities is a finish-to-finish link with an "Update Licensing Documents" activity that requires that documents are updated in time for review prior to fuel load. The other activities must be completed prior to this update activity, or are linked directly to start-up activities.

The logic within the licensing and ITAAC activities is reasonable for the level of definition provided.

4. Impact of Modularization

The information presented here is based on the modularization plan for the AP600. Since the AP1000 is largely the same design, just scaled up from the AP600, the information is considered applicable.

Modules are an integral part of the AP600 design concept. There are approximately 600 modules in the design. All the major pipe areas are modularized. Large modules carry 90% of the pipe, valves, and instruments for containment systems. Of all the pipe welds inside containment, 65% will be made in shops and shipped in modules.

There are five types of modules planned:

1. Mechanical Equipment modules – equipment on a common structural frame along with interconnecting piping, valves, instruments, wiring, etc.
2. Piping modules – pipe and valves and associated instrumentation on a common structural frame.
3. Electrical Equipment modules – electrical equipment on a common structural frame.
4. Structural modules – liner modules, wall modules, super floor modules, heat sink floor modules, turbine pedestal form modules, stair modules, platform modules, structural steel modules, space frame modules.
5. Wall, basemat, and floor reinforcement modules.

Some of the modules will be shop-assembled, some will be assembled on-site.

Westinghouse states that the total impact of modularization on the construction schedule has not been defined, but that the single largest driver of schedule reduction is modularization. Many critical path activities are planned to be shortened through modularization. The key components in Westinghouse's construction schedule are:

- On-site fabrication and lifting of completed reinforcement and structural modules into place.
- A modularized containment vessel, as opposed to piece-by-piece installation in a congested area.
- Liner modules that can be pre-assembled in parallel with other construction activities.
- Major piping and equipment modules in containment which are on critical path.
- Mechanical or electrical modules that must be installed before the floor steel above.

Without these aspects, Westinghouse's aggressive construction schedule will not be met.

5. CRITICAL PATH EVALUATION

The Westinghouse AP1000 critical path construction and commissioning schedule has evolved from their duration-based NOAK AP600 schedule. The AP1000 critical path schedule (Reference 5.5) includes 139 schedule items. Westinghouse reports that the AP1000 activity durations are the same as the AP600 activity durations and that schedule improvements have been made by improving the schedule logic. The AP1000 schedule includes 18 months for site preparation and mobilization, 36 months for plant construction (pour nuclear island basemat to fuel load complete), and 6 months from fuel load to commercial operation. The total AP1000 critical path construction and commissioning schedule is shorter than the stated 60-month schedule, thus including contingency and margin.

Procurement Phase

The AP1000 critical path schedule does not consider procurement issues. Rather, procurement assumptions have dictated that orders are placed for procurement early enough in the schedule so that they will not become critical. Note, however, that procurement issues could impact the AP1000 critical path schedule if not properly handled. In order to not impact the critical path, most major equipment fabrication could be started at the start of site preparation.

Site Preparation Phase (18 Months)

The site preparation phase starts with site clearing and grubbing followed by removal of top soil, establishing backfill borrow pits, and excavation and installation work associated with underground utilities. Following this, activities associated with excavation for the nuclear island begin. Excavation activities end with the completion of rock excavation, if necessary. We note that the critical path schedule shows two months of float during the same period that Westinghouse's nuclear island schedule shows that field assembly of the containment vessel bottom head and fabrication of the cradle rebar module are occurring. Critical path schedule development is expected to show critical path activities during this period. Critical path activities begin again following this float period with the installation of french drains, sumps, and catch basins. Next, a basemat working slab is installed. A prefabricated lower basemat rebar module, upper rebar chairs, embedded piping, a prefabricated upper basemat rebar module, and formwork are installed during the final months.

Eighteen months is considered a reasonable schedule for site preparation, underground utility installation, circulating water piping, nuclear island foundation excavation, and preparations for pouring the nuclear island basemat.

Underground utility and circulating water piping installation must be completed during the site preparation period to allow for the mobilization and movement of the 1200-ton crane that is used to set rebar modules and the lower containment head during the first month of plant construction.

We note that site mobilization and the construction of a significant number of temporary facilities occur during the site preparation period.

Construction Phase (36 Months)

Major plant construction begins with the first concrete pour for the nuclear island basemat. After this activity, the following activities are critical as the plant construction continues.

- Installation of pedestal rebar modules, pedestal concrete, cradle rebar module, and setting the containment vessel bottom head.
- Welding embedded piping to the containment vessel head, setting two room modules, and placing concrete under the containment vessel.
- Forming and pouring concrete walls to elevation 84', a hold period between concrete placement and epoxy coating, and epoxy coating concrete in Area 4.
- Installation of the resin slurry system at elevation 66', the lowest containment building level, and floor construction at elevation 84' 6" in Area 4.
- Critical path continues in Areas 3 and 4 of the containment with equipment and floor installation up to elevation 118'.
- Additional floor and wall construction activities.

Westinghouse has recognized that building-to-building relationships are important. Certain Auxiliary Building exterior wall placements are necessary before construction can begin on the Annex Building and the Turbine Building basemats. Additionally, completing the Auxiliary Building north wall is a necessary prerequisite to Turbine Building south bay construction activities. Completing exterior wall construction activities ensures that other building activities are not delayed and ensures that activities outside the nuclear island do not become part of the critical path. Construction continues with the activities listed below, which are performed in the sequence listed.

- Piping module installation, Auxiliary Building tank and chiller installation, a piping integrity check, installation of the Chemical and Volume Control System, and setting the passive Residual Heat Removal (RHR) Heat Exchanger and an associated RHR module.
- Installation of columns, structural steel, and grating and a two-week Christmas and New Year break.
- Completing steel and deck work, removing a temporary containment cover, concrete work, placing main loop piping, and reinstalling the temporary containment cover.
- Pipe connections inside containment.
- Additional piping work and setting the containment vessel top head.
- Critical path activities then involve erecting the ring platform, setting a valve room and stair modules, completing the walls, floors, and roof for the Passive Containment Cooling System (PCS), erecting the precast shield roof module, installing rebar, forms, and placing the shield roof, installing the PCS tank module, placing PCS module exterior walls, and placing the concrete for the PCS modules exterior walls.
- The Hot Function Test is performed followed by additional testing activities.
- Nuclear island construction activities except for fuel load are completed. Next, the turbine roll is accomplished using steam generated during the Hot Function Test. The turbine roll is the only non-nuclear island activity listed on the critical path schedule.
- After initial plant cool down, the containment leak rate test is performed.
- Technical Specification surveillance is completed and open items are closed.
- The fuel load is completed.

Westinghouse has worked to minimize the critical path length and to ensure that the project critical path remains inside the nuclear island. Westinghouse reports that they have sufficient confidence that they are willing to guarantee a plant construction schedule of 36 months from first concrete to fuel load.

Commissioning Phase (6 Months)

Following fuel load, Technical Specification surveillance for initial criticality is completed during the final parts of the construction phase. The commissioning phase critical path then proceeds through lower power/initial criticality and power ascension testing. Following these commissioning activities, the AP1000 is ready for commercial operation.

Six months are included in the schedule after the fuel load for power ascension testing and achieving commercial operation. These six months include extra contingency time, which is considered reasonable, for dealing with any plant start-up problems.

Near Critical Paths

Five near critical paths were identified by Westinghouse for the AP600 schedule presented in Reference 5.2. The near critical paths include:

- 1st Near Critical Path: This path looks similar to the critical path except it includes the below grade Auxiliary Building mechanical items. Epoxy coatings in the Auxiliary Building also show up as potential problems.
- 2nd Near Critical Path: This path also runs through the Nuclear Island excavation and concrete placement and the below-grade Auxiliary Building walls. It also includes the upper elevations of the Auxiliary Building walls.
- 3rd Near Critical Path: This path includes activities in the Turbine Building such as mechanical modules, the assembly and installation of the condensers, and completion of piping systems. Late completion of the construction could lead to late start-up testing and hydro of the secondary side followed by major plant start-up activities.
- 4th Near Critical Path: This path also identifies the Auxiliary Building interior walls, the turbine condenser related piping, and the cooling water piping as potential critical items.
- 5th Near Critical Path: This path adds additional liner modules for the in-containment concrete and additional structural steel around the steam generators and pressurizer.

Westinghouse used the information from these near critical path schedules to identify areas that needed scheduling attention and refinement. Information learned during the AP600 schedule development and review has been used to refine the AP1000 schedule.

Because of the additional development since the critical path review of the AP600 schedule, the near critical paths discussed here may not represent the current near critical items in the AP1000 construction schedule. However, it is likely that the shortening of the schedule from what was achieved for the AP600 schedule to the AP1000 schedule has placed additional pressure on the turbine building schedule. It is anticipated that additional activities in the turbine building may become near critical path activities. Extra care will be needed to ensure turbine building activities do not slip and become critical path activities during the construction of the AP1000 nuclear plant.

A review of current near critical paths would be useful in the further development of the AP1000 schedule.

Critical Path Evaluation Conclusions

Westinghouse appears ready to guarantee a total AP1000 plant construction and commissioning schedule of 60 months. This 60-month schedule includes contingency time that increases the confidence in success.

Additional time will be required for procurement activities not included in the critical path schedule. In particular, the reactor vessel and head will need to be purchased at least six months before the start of the schedule. Site-specific engineering and procurement activities would need to start prior to ordering the reactor vessel and the reactor head.

Start-up testing activities begin around the 9th month of construction and continue in parallel with nearby construction activities. Careful scheduling will be needed to ensure that commissioning activities do not interfere with ongoing construction activities. Westinghouse has used their 4D schedule (incorporating a 3-dimensional model of the plant) to evaluate the activities that are conducted in parallel to look for work interferences. This effort has eliminated problems, but attention should continue to be paid to the location of activities.

Additional construction labor may be needed to support testing activities so that labor dedicated to construction activities is not diverted to support start-up activities. The period from the start of system testing until fuel load appears to be sufficient; however, planning and scheduling of these activities will be a challenge.

Plant operator support is necessary to support start-up testing activities. Unless further planning is performed, there is the potential that testing could interfere with operator training and simulator training activities.

6. First-Versus-Nth-of-a-Kind

The integrated AP1000 schedule has been developed as an NOAK schedule. Westinghouse appears willing to guarantee a 60-month schedule for plant construction and commissioning of the NOAK plant. This schedule includes 18 months for site preparation, 36 months for plant construction to fuel load, and 6 months for power ascension testing prior to commercial operation. COL application, engineering, and procurement activities would have to start well before the start of site preparation. The NOAK schedule shows these activities starting approximately one year prior to the start of site-preparation activities and continuing in parallel with initial site preparation.

In order to achieve the accelerated schedule for COL application preparation and submittal, Westinghouse has assumed that they will be able to have "pre-approved" sections of the COL application available for use by the owner. These sections would presumably be available from prior COL applications and relate to those items that are not site specific. Using this methodology, Westinghouse assumes that the NOAK COL application preparation and review durations will be quite short.

Westinghouse also appears ready to support a 60-month schedule from the start of site preparation to commercial operation for a FOAK plant. However, in this case the early licensing, engineering, and procurement activities associated with a FOAK plant are expected to take approximately one year longer than the same activities associated with an NOAK plant. See Figure D-1 below for a summary of the proposed FOAK versus NOAK schedules.

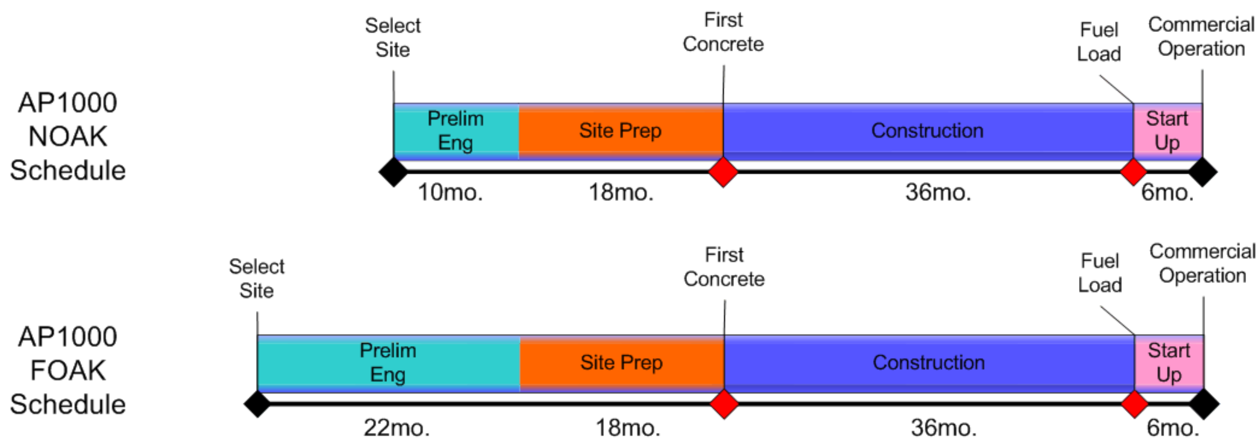

Figure D-1. AP1000 NOAK vs. FOAK Schedules

This difference between the FOAK and NOAK schedules indicates that Westinghouse is highly confident in their 60-month overall construction schedule. Given the margin that has been achieved in their current critical path schedule, this may be reasonable, but adds considerable risk to the FOAK schedule.

Westinghouse has spent a considerable effort investigating the cost differences between a single FOAK plant, twin FOAK plants, single NOAK plant, and twin NOAK plants. This information is documented in Reference 5.1. They have estimated a learning curve between FOAK and NOAK plants of 92.17% (applied to direct and indirect labor hours). If that is translated into a man-hour increase for the FOAK plant due to rework and reduced worker efficiency/productivity, then the FOAK construction schedule would be 8.5% longer than the anticipated NOAK schedule. This leads to a potential lengthening of the 60-month schedule by as much as 5 months. If there is a high confidence that the NOAK plant can be constructed within 60 months, then our chances for constructing the FOAK plant within the same duration are somewhat lower. The eventual contractual arrangements for the FOAK plant will determine whether this risk is taken on by the owner, Westinghouse, or whether they decide to lengthen the projected FOAK project schedule.

In addition, the pre-construction COL, engineering, and procurement activity durations for the FOAK schedule appear to be somewhat optimistic. For the FOAK plant, there will be no benefit available from “pre-approved” COL application sections. It seems likely that Westinghouse will require more than the additional year to complete these activities, establish relationships with vendors, and other FOAK activities.

Another potential risk that will be added in the FOAK schedule is that NRC oversight and approvals prior to fuel load and after fuel load are also expected to take longer. This change is not reflected in the learning curve estimate discussed above.

7. Summary of Vendor Risk Assessment By Vendor

Westinghouse performed a schedule risk analysis for the AP600. This is documented in Reference 5.2. The duration of each activity in the AP600 schedule was assessed using a three-point system. The first point is the original activity duration that was estimated and used in the schedule. The second point is the lower limit or shortest duration possible for the activity if everything went exceptionally well. The third point upper limit is the longest duration possible if an activity was adversely affected by bad weather, labor problems, missing materials, or other problems. Once the upper and lower limits were established for each activity, a Monte Carlo program was used to run Critical Path Method (CPM) network calculations. The program uses a random selection of durations for each activity to predict the most likely project duration and to predict the probability of being over or under the original schedule duration. The program also establishes a criticality factor for each schedule activity that can be used to assess the likelihood of a schedule activity becoming critical. A Criticality Report was provided along with five near-critical paths (these were discussed previously). Westinghouse used the Monte Carlo 3.0 Project Risk Analysis Software by Primavera to analyze their Primavera schedule and produce the mentioned reports.

Table D-2 provides the schedule risk factors used to evaluate the AP600 schedule. Note that regulatory changes and design changes were assigned a 0% risk for the NOAK plant schedule being evaluated. No allowances were made for catastrophic incidents. We note that late delivery of major equipment or modules can be a significant risk factor especially when vertical construction is planned. For this NOAK plant, it was assumed that detailed delivery schedules were available from established vendors and that a modified "just-in-time" delivery schedule would be used to eliminate any impacts from late deliveries. We note that the risk rate percentage reported for Safety Problems appears to be misstated or overly optimistic. A risk rate percentage of -0 to +20 is considered a more appropriate rate. However, it is not believed that this misstatement would significantly affect the risk analysis.

Table D-2. Westinghouse AP1000 Schedule Risk Factors

Schedule Risk Factor	Risk Rate, %
Regulatory Changes	0
Design Changes to Standard Plant	0
Productivity (Shop, Site, In-the-Hole)	-45 to +25
Shift Work	-10 to +40
Just-in-Time Delivery	30 Days Float
Early Start Up Testing	-20 to +20
Safety Problems (Heavy Lifts, High Work, Vertical Construction)	-20 to +0
Weather Conditions	Calendar by Season
Errors in Design, Procurement, Construction	-0 to +20
Site Conditions (Access, Parking, Soil Stability, Material Availability)	-20 to +20
Vertical Construction	-5 to +20
Labor (Skill vs. Technology, No-Strike Agreement)	-20 to -40
Aggregate using MK weighted percent	-25 to +20
Recommendation: Use 10,000 Iterations	
Use -45% to +40% for Maximum Coverage	

The results of the Monte Carlo analysis confirm that it is possible to build the AP600 in 36 months within an 88% probability. While the analysis was performed for the AP600, based on the available information, we believe a similar probability would also apply to the 36-month AP1000 schedule.

Table D-3. Westinghouse AP1000 Schedule Evaluation: Engineering Phase

Activity	Scope	Duration	Logic
A. Conceptual and Preliminary Design[a]			
Discipline Specific	There are few conceptual and preliminary engineering activities in the schedule. Those preliminary activities that are identified include primarily site-specific items related to water supply, electric grid studies, polar crane selection, and the like. Many of these activities support preparation of the COL application. Additionally, the establishment of a QA program is included in the schedule. The limited engineering scope is appropriate for the NOAK schedule as most of this type of work is assumed to be complete from previous plant projects. The provided scope is complete.	The preliminary engineering activities span the period from site selection to COL application submittal. COL application preparation activities are not identified as engineering scope, but are detailed in the concurrent and interrelated licensing schedule. The duration of preliminary engineering activities totals approximately 14 months. The duration of these tasks is reasonable.	Engineering activities are initiated in the schedule by the selection of the plant site. Site selection (a licensing activity in the schedule) has no predecessor and is one of the key starting points for the schedule. The logic between preliminary engineering activities and the COL application and procurement activities appear to be complete and appropriate for the NOAK schedule.
Simulator	There are no simulator activities identified in the schedule.	N/A	N/A
B. Detailed Design[a]			
Discipline Specific	Detailed engineering design activities occur both pre- and post-submission of the COL application and also include site-specific activities to design permanent and temporary infrastructure; adapt the standard storm and sewer drain design to the chosen site; and design raw water, circulating water, and utility piping layouts. Additionally, the emergency operations facility is located and the standard construction facility is adapted to the site in this schedule. The detailed engineering design activities are appropriate for the NOAK project. Note that the primary difference between the NOAK and FOAK schedules is within the engineering phase.	Pre-COL application submission engineering activities have a total duration of about 14 months. Post-COL application submission engineering activities have a total duration of about 11 months. The total duration for this effort is judged to be reasonable.	Detailed site design activities are logically linked to the site selection, COL application submission, initial yard work, and initial procurements. The logic is judged to be reasonable. There is no predecessor task given for the Selection of Meteorological Tower Location in the schedule. However, it appears that this activity has extremely low impact on the rest of the schedule, so this is judged to be acceptable.
Simulator	There are no simulator activities identified in the schedule.	N/A	N/A

Activity	Scope	Duration	Logic
Modules	There are no detailed design activities related to modules identified in the schedule. This is appropriate for the NOAK schedule which assumes a completed standard plant design.	N/A	N/A

References and Notes:

a. This table was created using information from Reference 5.3.

Table D-4. Westinghouse AP1000 Schedule Evaluation:
Procurement Phase

Activity	Scope	Duration	Logic
A. Component Procurement			
Long Lead Items	The schedule identifies the following long-lead items: Reactor Vessel with Internals and Integrated Head Package, Pressurizer, Main Steam Turbine/Generator, PXS and RCS Squib Valves, Reserve Unit Aux Transformer, and Steam Generators. The procurements for the Squib valves include a "Build and Qualify" step that is not included for other activities. This is assumed to be an anticipated shop-testing requirement. The additional level of detail for this item is valuable. Overall, the long-lead item scope is considered to be complete.	The overall duration for long-lead procurements is approximately 3.5 years. Overall durations for major procurements including BEA, fabrication, and delivery are summarized below. Reactor Vessel with Internals and Integrated Head Package 33 mo. Pressurizer: 39 mo. Main Steam Turbine/Generator: 39 mo. RCS Squib Valves: 24 mo. PXS Squib Valves: 27 mo. Reserve Unit Aux Transformer: 18 mo. Steam Generators: 33 mo. These durations are judged to be reasonable. Critical path for the overall schedule would not be impacted if all long-lead items were procured starting at site preparation for all long-lead items except the Reactor Vessel. Westinghouse reports the Reactor Vessel fabrication would have to start 6 months before the start of site preparation if the Reactor Vessel and Reactor Head are pressure tested separately or 9 months if tested as a unit.	Procurement activities for long-lead time items are started as soon as the QA programs associated with procurements are available. This occurs prior to COL application submittal. Long-lead procurements are followed by additional procurement activities and their installation into the plant. The general logic for the procurement schedule is judged to be reasonable. The Steam Generators are considered a long-lead item in the schedule by virtue of the early start date. However, unlike the other long-lead items, the SGs are not identified with the early start predecessor. This is apparently a missing link in the Primavera schedule and does not affect the overall schedule The procurements of the PXS and RCS Squib valves are initiated with a "Find PXS Squib Valve Vendor" and "Find RCS Squib Valve Vendor" activities, respectively. This activity does not appear to be consistent with the assumption that all major vendors are available from previous projects. However, as it is conservative, this logic is considered to be reasonable.

Activity	Scope	Duration	Logic
Bulk Materials	Very few bulk material procurements are identified in the schedule. The only clear bulk materials that are included are valves. The schedule is organized such that commodities are procured by system and modules rather than by bulk material type. Concrete procurement was not located within the schedule and appears to be missing. However, establishment of the required batch plants are included in the Site Preparation activities. The bulk materials procurements are judged to be complete given the approach to the procurement schedule organization.	N/A	N/A
Shop-Testing and Qualification	Shop-testing activities are not included in the schedule; however, Westinghouse indicates that shop-testing activities have been considered and allowed for within the overall procurement durations.	It is expected that with further schedule development the procurement durations for some activities are too short to support the required testing activities, while others are conservative. Further development should be conducted to evaluate the potential impacts of testing on the procurement schedule.	N/A
Transportation	Delivery activities are identified for all major components and modules. Delivery activities are not separated out for material procurements that feed into module fabrication. The delivery scope appears to be complete.	In general, delivery durations are 24 days, or 1 month. However, the durations range from 5 to 42 working days. All vendors are assumed to be within the U.S., thus allowing for truck or rail shipment within the allotted durations. In general, the durations appear to be reasonable. Current transportation durations appear too short if international/ocean delivery is necessary for large long-lead items.	Delivery activities follow procurements and precede installation and construction activities. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
B. Module Fabrication and Assembly			
Shop Fabrication and Assembly	Module procurements make up the majority of the procurement activities, and are highly detailed. Modules include four major types: Mechanical Equipment Modules Electrical Equipment Structural Modules Piping Modules Many modules are actually sub-modules that are then assembled on-site into larger modules. The scope of the module procurements is judged to be complete and of a sufficient level of detail.	The schedule includes a Bid, Evaluate, and Award period of 20 to 60 working days, an equipment procurement period of 56 to 70 days, and a variable fabrication and delivery period. Typically, the fabrication durations are of the ranges provided below: Mechanical/Electrical Equipment Modules: 7 to 14 mo. Structural Modules: 4 to 8 mo. Piping Modules: approx. 9 mo. The durations for procurement activities are judged to be reasonable, but are highly dependent upon availability of fabricators.	Module fabrication logically follows the BEA period and procurement of materials and commodities for the module. There are typically no predecessors for module BEA periods. Once the module is fabricated and assembled it is shipped to the site and links with construction activities. This logic is judged to be reasonable for the NOAK schedule.
Shop-Testing and Qualification	Shop-testing and qualification activities are not shown in the procurement schedule (with the exception of the squib valves). Westinghouse indicates that testing and qualification activities will be performed in the shop, with receipt inspections at the site. This is judged to be reasonable. Additional detail will be required prior to actual start of procurements.	It is expected that with further schedule development, the procurement durations for some activities are too short to support the required testing activities, while others are conservative. Further development should be conducted to evaluate the potential impacts of testing on the procurement schedule.	N/A
Transportation	Delivery activities taking completed modules from the fabricator to site are included for all module procurements. Delivery is assumed to be by truck or rail with a maximum module size of 12' W x 80' L. The delivery schedule scope is judged to be complete.	Typically, 28 working days are allowed for delivery. This duration is expected to be achievable for most modules fabricated within the U.S. However, achieving the required receipt inspections within this timeframe may be challenging depending on the number of modules to be inspected within one period of time.	The transportation of modules from the shop to the site is preceded by module fabrication and followed by construction activities. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
On-site Fabrication and Assembly	When required, AP1000 will assemble the largest shippable sub-modules together to create a single module that can be lifted into the building. An example of where this technique is used includes the fabrication of large rebar modules as well as the containment vessel head. This scope is judged to be complete.	The duration to complete the on-site assembly of modules is from 20 to 65 working days. This duration is considered generally reasonable; however, design information was not reviewed to determine whether the specific activities required would be able to be performed within this timeframe.	On-site module assembly is preceded by delivery to the site and followed by setting the module into the building. This logic is judged to be reasonable.

References and Notes:

a. This table was created using information from References 5.2 and 5.3.

Table D-5. Westinghouse AP1000 Schedule Evaluation:
Construction Phase

Activity	Scope	Duration	Logic
A. Site Preparation			
Soil Preparation	Soil preparation activities include: Clearing, grubbing, removing top soil, and establishing backfill borrow pits. This scope is judged to be complete. In addition to standard site preparation activities, several major construction excavations take place during site preparation. Excavation for the Nuclear Island includes: Excavate soil, rock removal as necessary, place french drains, place sumps, placing basemat working slab. Note that Turbine Building excavation is also accomplished during this period.	The duration allowed for soil preparation activities is 3 months. Nuclear Island and Turbine Building excavation duration is 8 months. These durations are judged to be reasonable.	Soil preparation activities are the earliest activities performed during site preparation period. Site preparation is preceded by NRC issue of the Limited Work Authorization (LWA) and some site-specific engineering. This logic is judged to be reasonable. The one activity on-site that seems to precede these activities is the installation of water intake and discharge piping. The nature of this task is unknown but is linked with site support engineering. This may be an error within the schedule; however, the 3-month task is not expected to impact the critical path of the schedule. Excavation activities follow the formwork laydown areas and some temporary utilities. Excavation is followed by transformer installation and placement of rebar modules. This logic is judged to be reasonable.
Laydown Area Preparation	Establishing, grading, and graveling of laydown areas including a formwork laydown yard are include in the site preparation schedule. This scope is judged to be complete.	The duration of these activities is 4 months. This duration is judged to be reasonable.	This activity is preceded by initial excavation activities for utilities and following the start of road construction. This activity is followed by initial excavation of the Nuclear Island and establishing of storage piles. This logic is judged to be reasonable.
Storage Area Construction	There are two warehouse construction activities in the schedule: Build Class C warehouse Build Class A/B warehouse This scope is judged to be complete.	Each of these buildings takes 2 months to construct and are constructed in series for a total of 4 months. Design details are unknown; however, these durations appear reasonable.	Warehouse construction follows the concrete batch plant, carpenter formwork shop, and receipt of construction permits. These activities are conducted in parallel with the Admin Building construction and are followed by erecting modules and start of the radwaste building construction. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Equipment Assembly Area	Assembly area preparation activities include placing of slabs for formwork and foundation for erection pads and platens, construction of a fabrication shop, and establishment of crane pads. Installation of underground utilities and the circulating water piping to cooling tower is also performed during site preparation to allow for assembly of the Lampson Heavy-Lift Crane and Other Cranes. This scope is judged to be complete.	Durations for some of the equipment assembly area site preparation activities are provided: Placing formwork slabs: 1 mo. Containment vessel erection pads: 2 mo. Foundation and placement of module erection platen: 5 mo. Fabrication shop: 2 mo Crane pads: 3 mo. Underground utilities: 6 mo. Circulating water piping: 4 mo. Crane Assembly: 3 mo. These durations are considered reasonable.	Equipment assembly area preparations follow initial site preparation activities such as layout and soil preparation. They are followed by initial construction activities such as module assembly and crane and other major equipment assembly. Underground work is done concurrently during the site preparation phase to allow crane area preparation and crane mobilization. The Heavy-Lift Crane must be ready to set basemat rebar modules during site preparation period and must be ready for several heavy lifts during the first construction month. This logic is judged to be reasonable.
Road & Rail Construction	Road and rail construction including layout, excavation, installation of culverts, and installation of the road base occur during site preparation. This scope is considered complete.	Road and rail spur construction duration is 3 months. This duration is considered reasonable.	Layout, excavation, and installation of road bases and rail spurs occur early in the site preparation period and are followed by installation of temporary site utilities. This logic is judged to be reasonable.
Security Construction	Security construction includes installation of the site security fence, guard office, construction fences, and access gates. This scope is judged to be complete.	Initial security fences are installed in 2 months. Construction fences are constructed in 2 months later in the schedule. These durations are judged to be reasonable.	The site security fence is installed starting in the second month of site preparation during initial soil preparation activities. Construction fences are started in the sixth month of site preparation and are coordinated with the fire protection water main and parking lot construction. This logic is considered reasonable.
Temporary Office Space and Services	Installation of temporary buildings and services includes items such as temporary parking lots, temporary compressors, temporary power, temporary sanitary facilities, change/lunch rooms, and craft support facilities. This scope is judged to be complete.	Most of the temporary buildings and services are constructed within 6-9 months. This duration is considered reasonable.	These activities begin at the start of site preparation. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
B. Building Construction			
Reactor Building **(Containment Vessel, Shield Building)**	Numerous rebar modules are fabricated during the site preparation period to allow immediate pouring of the Nuclear Island basemat and to expedite construction during the early construction months. The Containment Vessel Bottom Head is fabricated on-site to allow setting the CV Bottom Head during the first construction month. The reactor building for the AP1000 consists of the containment and shield buildings. These are constructed with an open-top construction technique that allows for heavy lifts of rebar modules, structural modules, major equipment, equipment modules, and piping modules. Modularization allows for the rapid construction of this and other buildings. This scope is judged to be reasonable.	Durations for major reactor building activities are provided below from the critical path schedule: Construct rebar modules: 9 mo. Field assemble containment vessel bottom head: 3 mo. Place basemat: 2 days Setting modules: 2 days Setting Steam Generators: 1 mo. Setting Reactor Vessel: 20 days Containment Vessel: 24 mo. Shield Building: 27 mo. These durations are considered reasonable yet optimistic as they do not include the margin that is included in the advertised 36-month construction schedule.	Modules assembled during site preparation are started following availability of assembly areas. Installation of the basemat rebar modules also occurs during site preparation. First concrete is the official start of the plant construction phase and follows the readiness of the excavation and rebar modules. It also follows issue of the COL. Reactor building construction proceeds by placing modules into the building from bottom to top using an open-top construction method. Placement activities are followed by piping and installation activities, and eventually system testing. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Auxiliary Building	The AP1000 Auxiliary Building is part of the Nuclear Island. It shares the basemat with the reactor building. Major areas of the building include the Fuel Handling End, Center Area, Main Control Room, & Electrical Equipment End. Construction is achieved in much the same manner as the Reactor Building with open-top construction and module installation.	The Auxiliary Building is completed in 27 months. Key activity durations include: Exterior Walls to El. 100': 2 mo. Set M-20 Super Module: 2days Electrical Below El. 100': 5 mo. HVAC Below El. 100': 9 mo. Piping Below El 100': 13 mo. Walls to El.156',163',180': 5mo. Electrical 100' to Roof: 20 mo. Shield wall to El 246': 16 mo. Modules, steel, deck, & concrete to 107', 11', 135': 5 mo. Modules, steel, deck, & concrete 163' & 180': 12 mo. HVAC El. 100' to Roof: 14 mo. Modules, steel, deck, & concrete 149' & 156': 3 mo. These durations are considered reasonable yet optimistic as they do not include the margin that is included in the advertised 36-month construction schedule.	Auxiliary Building construction activities proceed from first concrete, through setting of the M-20 super module (which has its own temporary roof), and proceeds with wall and module installation activities with electrical, piping, and HVAC activities following by area and elevation. Completion of Aux Building construction activities is followed by turnover and system testing. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Turbine Building	Turbine building construction consists of building basemat rebar modules followed by formwork and concrete pours. The building is broken down into bays and only makes partial use of open-top construction techniques.	The overall duration of the Turbine Building construction is 24 months. Durations of major activities are provided below. Turbine Bldg Basemat: 5 placements of 1 to 2 days each over 10 months. Install Equipment and Modules: 4 mo. Structure to El. 161': 16 mo. Field assemble and install condensers: 7 mo. Field Assemble and set stator, turbine generator: 8 mo. Electrical: 19 mo. HVAC: 14 mo. Piping: 12 mo. Install CWS Piping and water boxes: 4 mo. Turbine pedestal placement: 5 mo. These durations are considered reasonable yet optimistic as they do not include the margin that is included in the advertised 36-month construction schedule.	Turbine Building construction begins in the site preparation phase with module and rebar assembly activities. Placement of equipment and modules begins as soon as the Turbine Bldg basemat is available. Construction proceeds with installation of structural modules, concrete, installation of the condensers, turbine pedestal placement and ongoing piping, HVAC, and electrical activities. These activities are carefully planned to ensure the many near-critical path activities do not become critical.
Radwaste Building	The construction activities for the Radwaste building are defined primarily by building area and discipline. Specific equipment installation is not identified. This scope is judged to be sufficient, but will require further definition.	The total duration for the Radwaste Building construction is 11 months. Individual activity durations are relatively short ranging from 2 to 30 days. These appear to be reasonable with the prefabricated approach that has been taken to construction.	Construction begins in the ninth month of plant construction following the completion of all temporary and permanent construction facilities. Radwaste building completion is followed by testing activities. Since the construction of this building is off the critical path, this placement is considered reasonable.
Diesel Generator Building	There are approximately 80 Diesel Generator Building construction activities. The scope is defined to an appropriate level of detail and is judged to be complete.	The total duration for Diesel Building construction is 9 months. This duration is judged to be reasonable.	Construction starts in the tenth month of plant construction following some Annex Bldg activities and excavation activities for the diesel supply lines. Diesel Building Construction is followed by testing activities. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
Annex Building	The Annex Building is the main personnel entrance to the plant and thus includes access to the clean areas of the Nuclear Island. It also includes health physics, locker rooms, etc. Construction activities are defined by 4 building areas, including the High Bay, Low Bay, and Change Rooms. Schedule definition is judge to include sufficient detail and a complete scope.	The total duration for Annex Building construction is 17 months. Piping: 14 mo. Electrical: 13 mo. HVAC: 14 mo. This duration is judged to be reasonable.	Annex Building construction activities must be coordinated with the Auxiliary Building because of the close proximity. The construction proceeds with construction of the basemat, which follows early concrete placements in the Auxiliary Building. Start-up activities following completion of the building. This logic is judged to be reasonable.
Main Control Building	The main control room (MCR) within the AP1000 is part of the Auxiliary Building. Main Control Room construction activities are difficult to discern from the other Auxiliary Building activities. However, there appear to be about 10 activities within the Auxiliary Building construction activities that relate specifically to the MCR or the Data Display and Processing System (DDS). This scope appears to be complete but cannot be verified.	N/A	N/A
Administration Building	There are two phases of Administration Building construction that are defined by 2 activities within the schedule. The Admin Bldg construction scope will need to be developed further.	Erect Phase I Administration Building: 6 mo. Erect Phase II Administration Building: 3.5 mo. This duration is judged to be generally reasonable.	The Phase I Admin Bldg construction is during the site preparation period following roads, permits, and warehouses and prior to start of operator training. The Phase II Admin Building occurs during construction following excavation for underground piping near the turbine bldg and turbine bldg roof installation and prior to operator training on the simulator. This logic is judged to be generally reasonable.

Activity	Scope	Duration	Logic
Circulating Water Building	Circulating water system (CWS) construction includes the circulating water intake structure, CWS cooling tower, CWS intake canal, and circulating water pipe. This is judged to be complete.	Durations for key circulating water activities are summarized below. Excavate and install CWS intake and discharge piping: 3mo. Erect cooling tower and install internals: 6.5 mo. These are judged to be reasonable.	Many of the activities for CWS system installation begin in the early months of site preparation in order to allow the underground piping to be placed prior to the need for the cranes. Cooling tower erection is started as early as possible in plant construction after the nuclear island and turbine building basemats are poured. This optimizes the use of the concrete batch plants. Circulating water system completion is followed by system tests. This logic is judged to be reasonable.
Transformers and Switchyard	While there are multiple switchyard and transformer related procurements, there are only 2 activities for the construction of the transformers and switchyard. This scope is judged to be complete; however, development of further detail will be required.	The durations for the transformer and switchyard activities are as follows. Install Switchyard: 3 mo. Install Transformer Area: 1.5 mo. These durations are judged to be reasonable, but aggressive.	These activities take place during site preparation and the early portions of the construction period once the procurements are available. They are followed by start-up activities. This logic is judged to be reasonable.
C. System Completion and Turnover			
Transformers and Switchyard	No turnover activities were identified for the Transmission Switchyard and Off-site Power System.	N/A	N/A
Reactor Systems	System completion and turnover activities for AP1000 consist of construction and electrical checkouts, and piping integrity checks. Most of these activities are performed by building area rather than by system. Turnover activities that seemed to be related to the chosen system were evaluated for duration and logic. The scope reviewed appears to be complete. Note: Hydro Tests and other activities are evaluated in the Start-up and Commissioning Phase during System Testing and qualification.	The Reactor System, Reactor Coolant System, Normal Residual Heat Removal System, Chemical and Volume Control System, Steam Generator System, and Fuel Handling and Refueling Systems were reviewed. The total duration in which turnover activities are completed is 24 months. Turnover is completed as areas become available following construction. This is judged to be reasonable.	System turnover activities follow construction area activities and precede system qualification and testing and start-up activities. This is judged to be reasonable.

Activity	Scope	Duration	Logic
Safety Systems	System completion and turnover activities for AP1000 consist of construction and electrical checkouts, and piping integrity checks. Most of these activities are performed by building area rather than by system. Turnover activities that seemed to be related to the chosen system were evaluated for duration and logic. The scope reviewed appears to be complete. Note: Hydro Tests and other activities are evaluated in the Start-up and Commissioning Phase during System Testing and qualification.	The Passive Core Cooling System, Passive Containment Cooling System, Plant Protection and Safety System, and Class 1E DC and UPS Systems were reviewed. The total duration over which turnover activities are completed as areas become available is 25 months. This is judged to be reasonable.	System turnover activities follow construction area activities and precede system qualification and testing and start-up activities. This is judged to be reasonable.
Turbine Generator Systems		The Main Turbine System, Main Steam System, Condensate System, Circulating Water System, Main and Startup Feedwater System, and Main Generation Systems were reviewed. The total duration over which turnover activities are completed as areas become available is 20 months. This is judged to be reasonable.	System turnover activities follow construction area activities and precede system qualification and testing and start-up activities. Note some Circulating Water System activities were completed during the site preparation phase. This is judged to be reasonable.
Main Control Room Systems		The Plant Control System, Data Display and Monitoring System, Turbine Control and Diagnosis, and the Main Control Room Emergency Habitation System were considered in this section. The total duration over which turnover activities are completed as areas become available is 21 months. This is judged to be reasonable.	System turnover activities follow the construction area completions. Following turnover, system qualification and testing activities are performed. This logic is judged to be reasonable.
Simulator	AP1000 schedule does not include a simulator	N/A	N/A

Activity	Scope	Duration	Logic
Radwaste Systems	System completion and turnover activities for AP1000 consist of construction and electrical checkouts, and piping integrity checks. Most of these activities are performed by building area rather than by system. Turnover activities that seemed to be related to the chosen system were evaluated for duration and logic. The scope reviewed appears to be complete. Note: Hydro Tests and other activities are evaluated in the Start-up and Commissioning Phase during System Testing and qualification.	The Gaseous Radwaste System, Liquid Radwaste System, and Solid Radwaste Systems were reviewed. The total duration over which turnover activities are completed as areas become available is 5 months. This is judged to be reasonable.	System turnover activities follow construction area activities and precede system qualification and testing and start-up activities. This is judged to be reasonable.
Electrical Systems		The Main AC Power System, Non-Class 1E DC and UPS, Class 1E DC and UPS, Main Generation System, and On-site Standby Power Systems were reviewed. The total duration over which turnover activities are completed as areas become available is 21 months. This is judged to be reasonable.	System turnover activities follow construction area activities and precede system qualification and testing and start-up activities. This is judged to be reasonable.
Water Treatment Systems		The Demineralized Water Treatment System, Demineralized Water Transfer and Storage System, and Condensate Polishing Systems were reviewed. No turnover information is available on the Demineralized Water Treatment System. The total duration over which turnover activities are completed as areas become available is 21 months. This is judged to be reasonable.	System turnover activities follow construction area activities and precede system qualification and testing and start-up activities. This is judged to be reasonable.
Other Plant Systems		The Service Water System, several Cooling Water Systems, Fire Protection System, and several Ventilation Systems were reviewed. The total duration over which turnover activities are completed as areas become available is 23 months. This is judged to be reasonable.	System turnover activities follow construction area activities and precede system qualification and testing and start-up activities. This is judged to be reasonable.

References and Notes:

a. This table was created using information from Reference 5.3, 5.4, 5.5, and 5.6.
b. Reference Section 3.2.2 of Reference 5.2

Table D-6. Westinghouse AP1000 Schedule Evaluation:
Start-up and Commissioning Phase

Activity	Scope	Duration	Logic
A. System Testing and Qualification			
Transformers and Switchyard	The scope of testing and qualification activities for Transformer and Switchyard systems appears incomplete; startup activities associated with the Transmission Switchyard and Off-site Power System (ZBS) are omitted from the schedule.	No specific ZBS startup activities included in the schedule.	No specific ZBS startup activities are included in the schedule.
Reactor Systems	Startup activities associated with pre-operational testing and verification of the following systems are included in the schedule: • Reactor System (RXS) • Reactor Coolant System (RCS) The schedule includes startup of the auxiliary steam boiler, part of the Auxiliary Steam Supply System (ASS). Hydro, secondary hydro, and flush activities for the Steam Generator Blowdown System (BDS) are included, along with pre-operational testing and verification of temperature and flow, instrument calibration, and electrical and logic checkout. Several activities associated with the Steam Generator System (SGS) are included in the schedule, such as instrument calibration and logic and electrical checkouts. In general, the scope of testing and qualification activities for the reactor systems is adequate. However, it appears that pre-operational testing and verification of the SGS is missing from the start-up and commissioning schedule.	The durations of individual activities associated with the reactor systems range from 1 to 10 working days. This is judged to be reasonable.	Hydro of system piping is scheduled after the completion of the associated piping system and appropriate piping integrity checks. Electrical checkouts are scheduled after connection of power to system components, and logic checkouts are scheduled after installation of DPUs. In particular, ASS startup is scheduled after electrical checkout in the Turbine Building, RXS activities are scheduled after the appropriate completion of piping systems and after the connection of power to the CRDM, and RCS tests are scheduled after the completion of appropriate construction activities. The start-up and commissioning activities are scheduled prior to fuel load.

Activity	Scope	Duration	Logic
Safety Systems	Hydro, flush, instrument calibration, electrical and logic checkouts, and pre-operational test and verification activities are included in the startup schedule for the following systems: • Passive Containment Cooling System (PCS) (a system flush is not included) • Passive Core Cooling System (PXS) (a system flush is not included) • Normal Residual Heat Removal System (RNS) • Containment Recirculation Cooling System (VCS) (system hydro and flush are not included) In general, the scope of testing and qualification activities for the safety systems is adequate.	The durations of individual activities associated with the safety systems range from 1 to 10 working days. This is judged to be reasonable.	Hydro of system piping is scheduled after the completion of the associated piping system and appropriate piping integrity checks. Electrical checkouts are scheduled after connection of power to system components, and logic checkouts are scheduled after installation of DPUs. In particular, RNS testing and verification activities are scheduled after the completion of appropriate construction activities, e.g., verification of RNS connection to ZOS is scheduled after completion of the Diesel Generator Building. The start-up and commissioning activities are scheduled prior to fuel load.

Activity	Scope	Duration	Logic
Turbine Generator Systems	Instrument calibration, hydro and flush, electrical and logic checkout, and pre-operational testing and verification are included for the following: • Main Turbine and Generator Lube Oil System (LOS) • Condensate System (CDS) • Gland Seal System (GSS) (startup of system also included) • Main Steam System (MSS) • Main and Startup Feedwater System (FWS) Startups of systems: • Hydrogen Seal Oil Sys. (HSS) • Heater Drain System (HDS) • Main Turbine System (MTS) • Condenser Air Removal System (CMS) The scope of testing and qualification for the turbine generator systems appears incomplete. Specific pre-operational testing and verification of the HSS, the HDS, the MTS, and the CMS is not included. Startup activities associated with the Main Turbine Control and Diagnostics System (TOS) are not included.	For those systems that have only one activity listed in the schedule ("system startup"), the duration of the activity ranges from 10 to 22 working days for the various systems. The durations of individual activities associated with the remaining turbine generator systems range from 1 to 10 working days.	Hydro of system piping is scheduled after the completion of the associated piping system and appropriate piping integrity checks. Electrical checkouts are scheduled after connection of power to system components, and logic checkouts are scheduled after installation of DPUs. In particular, startup of the HDS is scheduled to occur after verification of flow from the TCS; FWS test and verification is scheduled after appropriate CDS activities are performed; startup of the GSS is scheduled after the performance of the turbine on the turning gear is verified; testing and verification of MSS operation is scheduled after FWS pump performance tests, after providing power to MSS MOVs, and after verifying CCS control circuits; and startup of the MTS is scheduled after verification of TCS flow and set of the MSS hydro skid. The start-up and commissioning activities are scheduled prior to fuel load.
Main Control Room Systems	Logic checkout and installation, setup, and testing of DPUs, and the verification of correct DPU operation are specified in the startup schedule for the following systems: • Plant Control System (PLS) • Protection and Safety Monitoring System (PMS) The scope of testing and qualification for the main control room systems appears incomplete; startup activities associated with the Data Display and Processing System (DDS) are missing from the schedule.	The durations of individual activities associated with the main control room systems range from 1 to 5 working days.	PLS and PMS activities are scheduled after appropriate electrical activities have been completed, such as cable terminations and electrical connections. The start-up and commissioning activities are scheduled prior to fuel load.

Activity	Scope	Duration	Logic
Simulator	There are no simulator activities identified in the schedule. This is deemed appropriate for the NOAK schedule, which assumes that a simulator design is available at other sites.	N/A	N/A
Radwaste Systems	Instrument calibration, hydro, flush, electrical and logic checkout, and pre-operational testing and verification are included in the startup schedule for the following systems: • Liquid Radwaste Sys. (WLS) • Spent Fuel Pool Cooling Sys. (SFS) • Gaseous Radwaste Sys. (WGS) • Solid Radwaste Sys. (WSS) The only Plant Gas System (PGS) activity included in the startup schedule is completion of piping; it appears that the full set of PGS startup activities is missing from the schedule.	The durations of individual activities associated with the radwaste systems range from 1 to 12 working days.	Hydro of system piping is scheduled after the completion of the associated piping system and appropriate piping integrity checks. Electrical checkouts are scheduled after connection of power to system components, and logic checkouts are scheduled after installation of DPUs. The start-up and commissioning activities are scheduled prior to fuel load.

Activity	Scope	Duration	Logic
Electrical Systems	Main AC Power System (ECS) activities in the startup schedule include the setup, energizing, and verification of MCC's, load centers, and 4160 switchgear. Non Class 1E DC and UPS System (EDS) activities include verification of load transfers and min voltage with batteries and with the diesel generators. Class 1E DC and UPS System (IDS) activities include the verification of load transfers with batters and from the ZOS. Special Monitoring System (SMS) activities in the startup schedule include instrument calibration and verification of proper system operation. On-site Standby Power System (ZOS) scheduled startup activities include hydro, flush, logic checkout, and instrument calibration. Startup of the Main Generation System (ZAS) is scheduled. The scope of testing and qualification of the electrical systems appears to be incomplete; specific pre-operational testing and verification of the ZAS are not included in the schedule, and startup activities associated with the Excitation and Voltage Regulation System (ZVS) are completely omitted from the schedule.	The durations of individual activities associated with the electrical systems range from 2 to 20 working days, where the 20 working days is for installation of batteries for the IDS. The only activity included for the ZAS is "system startup", scheduled for 5 working days.	ECS activities begin with the placement of MCC's, scheduled after appropriate floor slabs have been placed. Verification of the EDS with batteries is scheduled to begin after batteries have been charged through the ECS system. Verification of the EDS with the diesel generators is scheduled to begin after electrical checkout of the diesels. ZOS activities are scheduled after the completion of construction of the Diesel Generator Building. ZAS startup is scheduled after testing and verification of flows through the Turbine Building Closed Cooling Water System (TCS). IDS activities are scheduled to occur after the proper installation and setup of the electrical system. MCCs are energized to supply temporary power after the appropriate completion of the building in which each is located. The temporary power is supplied to components for completion of electrical checkouts for start-up and commissioning and other activities. Temporary power is supplied to the MCCs between months 13 and 18 of the construction schedule. Permanent power is not supplied until month 20 of the construction schedule. Therefore, many of the start-up and testing activities are performed using temporary power. The start-up and commissioning activities are scheduled prior to fuel load.

Activity	Scope	Duration	Logic
Water Treatment Systems	Hydro, flush, instrument calibration, electrical and logic checkout, and pre-operational testing and verification are included in the startup schedule for the following systems: • Demineralized Water Transfer and Storage System (DWS) • Chemical and Volume Control System (CVS) The scope of testing and qualification for the water treatment systems appears to be incomplete. Startup activities associated with the Demineralized Water Treatment System (DTS) are missing from the schedule.	The durations of individual activities associated with the water treatment systems range from 1 to 10 working days.	Hydro of system piping is scheduled after the completion of the associated piping system and appropriate piping integrity checks. Electrical checkouts are scheduled after connection of power to system components, and logic checkouts are scheduled after installation of DPUs. The start-up and commissioning activities are scheduled prior to fuel load.
Other Plant Systems	Hydro and flush, instrument calibration, electrical and logic checkout, and pre-operational testing and verification are included in the startup schedule for the following systems: Component Cooling Water Sys. (CCS) Turbine Building Closed Cooling Water Sys. (TCS) Circulating Water Sys. (CWS) Fire Protection Sys. (FPS) Hot Water Heating Sys. (VYS) Central Chilled Water Sys (VWS) Service Water Sys. (SWS) Annex/Aux Building Non-radioactive Ventilation Sys. (VXS) (hydro and flush are not specified) Radiologically Controlled Area Ventilation Sys (VAS) (hydro and flush are not specified) Nuclear Island Nonradioactive Ventilation Sys. (VBS) (hydro and flush are not specified) Containment Air Filtration Sys. (VFS) (hydro and flush are not specified)	For those systems that have only one activity listed in the schedule ("system startup"), the duration of the activity ranges from 5 to 20 working days for the various systems. The durations of individual activities associated with the remaining other plant systems range from 1 to 25 working days, where the 25 working days is for hydro of FPS yard piping.	Hydro of system piping is scheduled after the completion of the associated piping system and appropriate piping integrity checks. Electrical checkouts are scheduled after connection of power to system components, and logic checkouts are scheduled after installation of DPUs. In particular, containment vessel ILRT and SIT with the VUS are scheduled after construction of the containment vessel is complete, and blowdown of CAS piping is scheduled after appropriate piping integrity checks. The start-up and commissioning activities are scheduled prior to fuel load.

Activity	Scope	Duration	Logic
Other Plant Systems (cont'd)	Startup of the following systems is included in the schedule: Turbine Island Vents, Drains, and Relief Sys. (TDS) Secondary Sampling Sys.(SSS) Turbine Building Ventilation Sys. (VTS) Primary Sampling System (PSS) startup activities include sampling at all locations to verify flow. Compressed and Instrument Air System (CAS) activities include blowdown of piping in the Auxiliary, Turbine, Annex, Radwaste, and Diesel Buildings, instrument calibration, and testing and verification of proper system operation and performance. Containment Leak Rate Test System (VUS) activities include walk-down inspection of the system, containment vessel SIT and ILRT, isolation valve alignment, and fill and drain of systems as required. The scope of testing and qualification of the "other plant systems" appears to be incomplete. Startup activities associated with the Containment System (CNS) and Radiation Monitoring System (RMS) are missing from the schedule.	For those systems that have only one activity listed in the schedule ("system startup"), the duration of the activity ranges from 5 to 20 working days for the various systems. The durations of individual activities associated with the remaining other plant systems range from 1 to 25 working days, where the 25 working days is for hydro of FPS yard piping.	Hydro of system piping is scheduled after the completion of the associated piping system and appropriate piping integrity checks. Electrical checkouts are scheduled after connection of power to system components, and logic checkouts are scheduled after installation of DPUs. In particular, containment vessel ILRT and SIT with the VUS are scheduled after construction of the containment vessel is complete, and blowdown of CAS piping is scheduled after appropriate piping integrity checks. The start-up and commissioning activities are scheduled prior to fuel load.
<u>B. Fuel Loading</u>			
Fuel Loading	Fuel loading is a single activity in the schedule. This is judged to be complete.	Fuel load is scheduled for 23 days. This duration is reasonable.	Fuel load is scheduled to take place after the completion of containment vessel ILRT and SIT and after tech spec surveillance test open items are closed. Fuel load is scheduled to be completed before tech spec surveillance for initial criticality begins. This scheduling of fuel load is logical.

Activity	Scope	Duration	Logic
C. Final Commissioning			
Final Commissioning	Power range testing involves the performance of power ascension tests. Final Adjustment of Pressurizer Spray Valves involves the final adjustment of pressurizer spray valves after fuel load. Final Calibration of the Special Monitoring System (SMS) is performed after fuel load. Commercial operation marks the contract completion This scope is judged to be complete.	The durations of key final commissioning activities are provided. Power ascension tests: 4.5 mo. Pressurizer Spray valve adjustment: 1 day SMS Calibration: 2 days This is judged to be reasonable.	The power ascension tests are scheduled to begin after lowering power following tech spec surveillance for initial criticality after fuel load, and end prior to commercial operation. Pressurizer valve adjustment takes place after fuel load and just after the start of power ascension tests. SMS calibration takes place after fuel load and at the start of the power ascension tests. Commercial operation follows completion of power ascension tests. This is judged to be reasonable.

References and Notes:

a. This table was created using information from Reference 5.3.

Table D-7. Westinghouse AP1000 Schedule Evaluation: Training Phase

Activity	Scope	Duration	Logic
A. Operator Training			
Operator Training	There is one activity for operator training in the schedule. This is judged to not provide sufficient level of detail for review.	Operator training takes place over 30 months. This is generally reasonable, but the extent of the training to take place is unknown.	This activities starts following the completion of the Phase I Admin Bldg in the site preparation phase and must complete prior to Hot Function Test. This activity is shown as critical within the schedule with a constraint to finish just before the Hot Function Test. This logic is reasonable, but indicates that further development is necessary.
B. Operator Training on Simulator			
Operator Training on Simulator	There is one activity for operator training on the simulator in the schedule. This is judged to not provide sufficient level of detail for review.	Operator training on the simulator takes place over 11 months. This is generally reasonable, but the extent of the training to take place is unknown.	Simulator training is to begin following the completion of the Phase II Admin Bldg. Training must be completed prior to the Hot Function Test. This activity is shown as critical within the schedule with a constraint to finish just before the Hot Function Test. This logic is generally reasonable, but indicates that further development is necessary.

References and Notes:

a. This table was created using information from Reference 5.3.

Table D-8. Westinghouse AP1000 Schedule Evaluation:
Licensing and ITAAC Phase

Activity	Scope	Duration	Logic
A. Pre-Fuel Load			
Engineering Reviews **Module Shop Inspections** **On-site Construction Inspections** **Testing and Qualification Reviews** **Engineering Reviews**	The AP1000 schedule does not specifically identify Post-COL inspection activities. However, there are a number of licensing activities (approx. 60) that are included which could refer to either NRC reviews, the applicant's preparation for reviews, or these activities may encompass both in the single activities. The activities seem to fall into several broad categories: • ITAAC items: there are 2 ITAAC milestones (with zero duration) in the schedule that seem to be related to site preparation activities. • Establishment and review of programs and procedures. • Specific technical and programmatic activities. • Activities to support pre-fuel load tests. • Activities that occur just before fuel load. This scope is considered to be a good start at developing a schedule for the licensing and ITAAC activities that will need to occur prior to fuel load. The scope appears to cover many of the activities that will be required. Additional development will be required prior to implementation.	Durations for a sample of the activities within each category are provided: <u>Programs and Procedures:</u> RV Matl. Surveillance Pgm: 1 mo. Coating Program: 1 mo. Test Pgm. Org & Staffing: 2 mo. Test Specifics and Procs: 1 mo. Conduct of Test Pgms: 2 mo. Testing Interface Rqrmts: 1 mo. <u>Technical/Programmatic:</u> Execution of HF Eng Pgm: 18 mo. Operating Exp Review: 2 mo. Task Analysis: 1 mo. Main Control Room: 1 mo. Plant Staffing: 1 mo. Training Program Dvlpmt: 1 mo. Equipment Survivability: 3 mo. Bulletins & Generic Ltrs: 3 mo. <u>Pre-fuel Load:</u> RV Pres-Temp Lmt Curves: 1 wk. Iss. Fed Reg Notice for FL: 1 wk. RV Internals Vib. Predict: 2.5 mo. Security Plans, Org & Test: 7 mo. <u>Just in time for Fuel Load:</u> PCS Storage Tank Exam: 1 wk. As Built Summary Report: 1 mo. Valve In-service Testing: 2 mo. Piping Benchmark Program: 1 day Chgs to Ref Reactor Dsgn: 1 mo. Plant Specific Inspection Program: 4 mo. ASME Code and Addenda: 5 mo. SG Tube Integrity: 2 wk. Radiation Monitor Procs: 1 wk. The range of durations for some of these activities suggests that some are development, while others are review. In general, the durations seem reasonable, but further definition is required.	Many of the post-COL licensing activities are constrained to activities that lead directly to fuel load. The programs and procedures reviewed are generally required to be complete in time for the start of system testing, which begins 6 months into the construction period. The technical and programmatic activities tend to be preceded by COL issue and followed by updating of licensing documents, which then links to fuel load. Pre-fuel load activities are those that follow system completion and are required to support pre-fuel load tests. Activities that occur just prior to fuel load follow construction completion and are followed by fuel load. This logic is judged to be reasonable.

Activity	Scope	Duration	Logic
B. Post-Fuel Load			
Engineering Reviews	Following Fuel load, a tech spec survey must be conducted prior to initial criticality and power ascension tests. There are no clear inspection or licensing activities within the schedule that occur following fuel load. However, there are 3 activities that are scheduled to take place much earlier, but are allowed to take place after fuel load. These include the apparent review of the Turbine Maintenance & Inspection Plan, the Review and Evaluation of Test Results, and First Plant Only & Plant Only Tests. ITAAC will be required following fuel load and prior to commercial operation, but these are not included in the schedule. The scope for post-fuel load licensing activities appears to be incomplete.	Turbine Maintenance & Inspection Plan: 1 mo. Review and Evaluation of Test Results: 1 mo. First Plant Only & 3 Plant only Tests: 1 mo. These durations are judged to be reasonable.	These activities are scheduled to be completed significantly prior to fuel load, but the late finish is allowed after fuel load. The Turbine Maintenance & Inspection Plan may be completed as late as commercial operation. This logic is not well understood.
On-site Construction Inspections	There do not appear to be any on-site construction inspection following fuel load.	N/A	N/A

References and Notes:

a. This table was created using information from Reference 5.3.

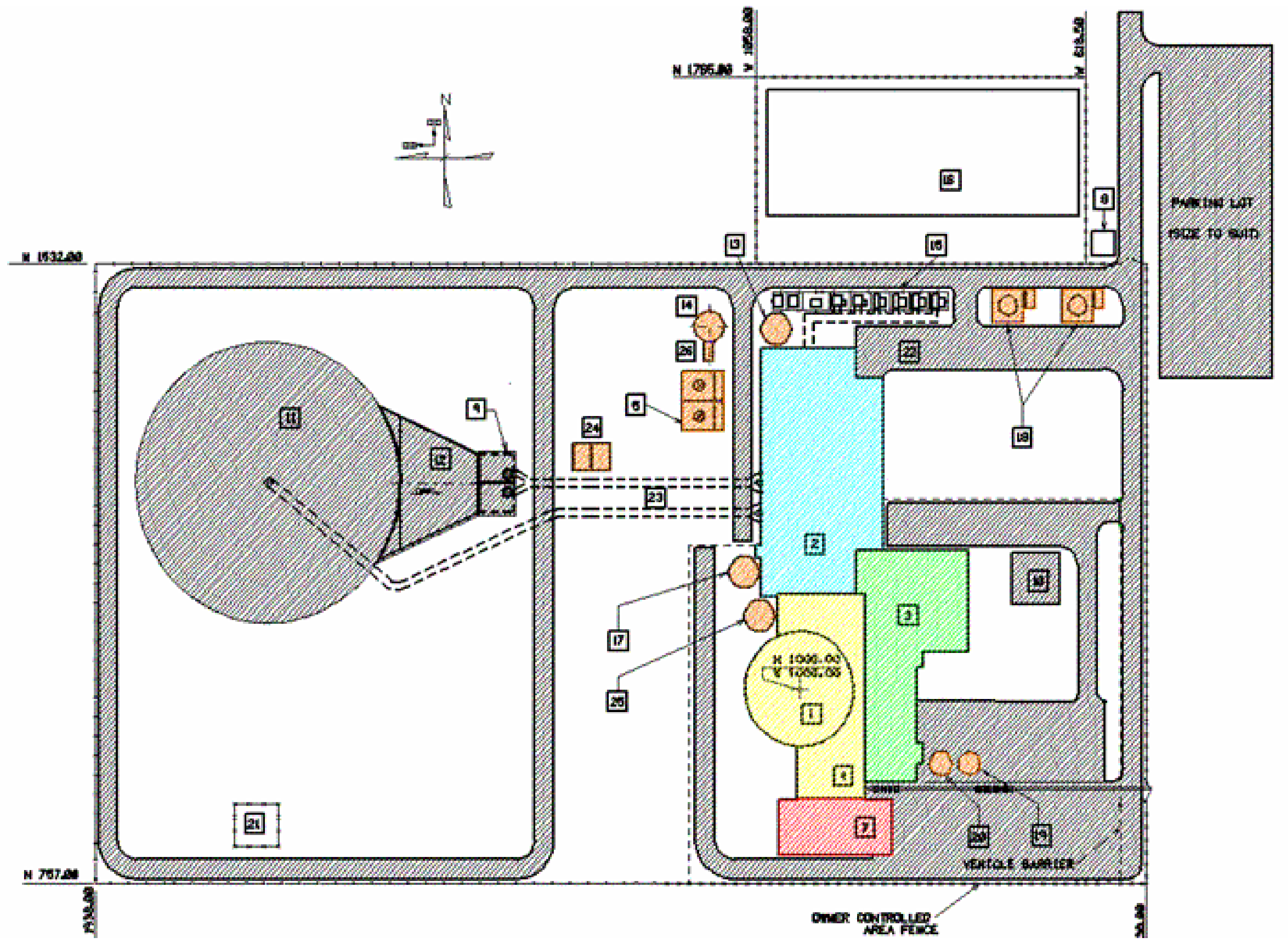

Figure D-2. AP1000 Plot Plan

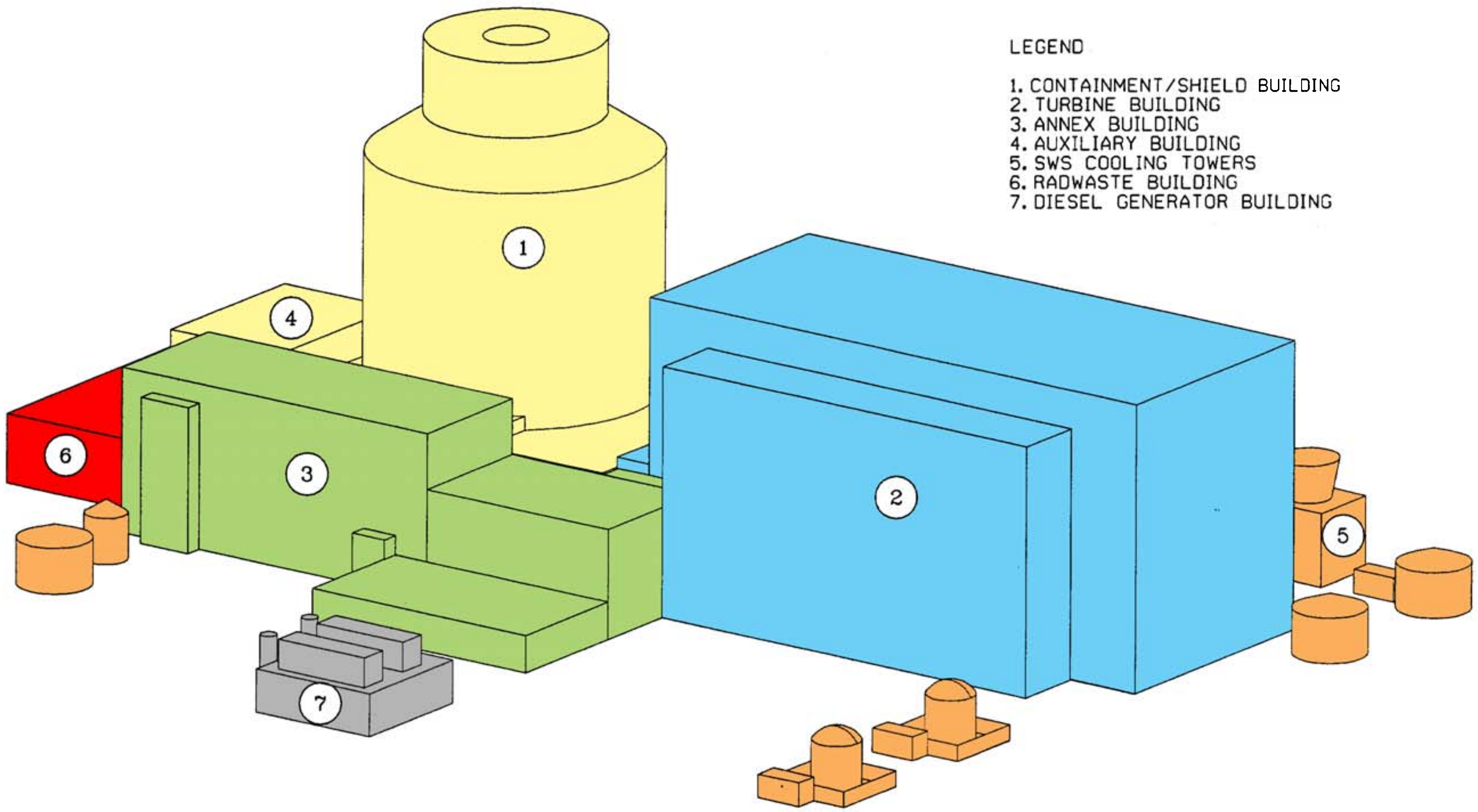

Figure D-3. AP1000 Building Arrangement

E

Glossary of Terms and Acronyms

ABWR Advanced Boiling Water Reactor

ACR Advanced CANDU Reactor

ACRS Advisory Committee on Reactor Safeguards; *an independent committee to the NRC that reviews and provides advice on nuclear reactor safety*

A/E Architect/Engineer

AECL Atomic Energy of Canada Limited

ALWR Advanced Light Water Reactor

AP1000 Advanced PWR 1000

ARC Advanced Reactor Corporation; *a consortium of operating electric utilities to oversee the development of advanced plant designs*

ASL Approved Supplier List; *the list of approved nuclear vendors for safety-related purchases and procurements*

BEA Bid Evaluate and Award

BOP Balance of Plant; *all systems, structures, components, and facilities of the plant not a part of or included in the nuclear island*

BWR Boiling Water Reactor

CED Contract Effective Date

COL Combined Construction and Operating License; *a phase in the new reactor licensing process as described in 10 CFR Part 52*

CP Construction Permit

CSTA Calandria and Shield Tank Assembly

DC Design Certification; *a phase in the new reactor licensing process as described in 10 CFR Part 52*

DEPSS Drywell Equipment and Piping Support Structure

DOE U.S. Department of Energy

EPC Engineer-Procure-Construct

EPRI Electric Power Research Institute

ESBWR Economic Simplified Boiling Water Reactor

ESP	Early Site Permit; *a phase in the new reactor licensing process as described in 10 CFR Part 52*
FMCRDs	Fine-Motion Control Rod Drives
FOAK	First-of-a-Kind
FOAKE	First-of-a-Kind Engineering
FWP	Feedwater Pump
GE	General Electric
HVAC	Heating, Ventilation, and Air Conditioning
I&C	Instrumentation and Control
ITAAC	Inspection, Tests, Analysis, and Acceptance Criteria
K-6/K-7	Kashiwazaki-Kariwa Units 6/7
LOCA	Loss of Coolant Accident
LOOP	Loss of Off-site Power
LWA	Limited Work Authorization
LWR	Light Water Reactor
M&E	Mechanical and Electrical
MCR	Main Control Room
MCC	Motor Control Center
N/A	Not Applicable
NOAK	Nth-of-a-Kind
NP2010	Nuclear Power 2010; *a program established by the DOE to deploy new nuclear power plants in the U.S. by 2010*
NRC	U.S. Nuclear Regulatory Commission
NPP	Nuclear Power Plant
NSP	Nuclear Steam Plant
NSSS	Nuclear Steam Supply System
NTDG	Near Term Deployment Group; *a group established by the DOE to examine prospects for deployment of new nuclear plants in the U. S. in this decade and to identify obstacles to deployment and provide action for resolution*
NUPIC	Nuclear Procurement Issues Committee
O&M	Operation and Maintenance
OL	Operating License
P&ID	Piping and Instrumentation Diagram
PCS	Passive Containment Cooling System

PHT	Primary Heat Transport
PRA	Probabilistic Risk Assessments
PSAR	Preliminary Safety Analysis Report
PWR	Pressurized Water Reactor
QA	Quality Assurance
RCCV	Reinforced Concrete Containment Vessel
RFC	Release for Construction
RFF	Release for Fabrication
RIP	Reactor Internal Pump
RPV	Reactor Pressure Vessel
“SAYGO”	“Sign As You Go”
SIT	Structural Integrated Test; *a test to measure strains in the containment structure*
SSCs	Systems, Structures, and Components
SSLC	Safety System Logic Control
TEPCO	Tokyo Electric Power Company
TMI-2	Three Mile Island – Unit 2
URD	Utility Requirements Document; *a document prepared by the ALWR program team that outlines requirements for future Light Water Reactor designs*
VHL	Very Heavy Lift (crane)
W	Westinghouse Electric Company
WBS	Work Breakdown Structure