Executive Summary

Duke Energy engaged Zapata Incorporated (ZAPATA) in March 2012, to identify and evaluate risks associated with the Crystal River 3 (CR3) Containment Restoration Project. On 2 July 2012, Duke Energy and Progress Energy merged, adding the Crystal River Facility to the Duke Energy nuclear fleet. Those entities that belonged to Progress Energy prior to the merger will continue to be referred to as Progress Energy, or Progress, in this report to avoid confusion.

In 2011, Progress Energy contracted Bechtel Power Corporation and URS Corporation to develop and design a plan to restore the containment facility per the Option 10 repair concept developed by Bechtel. The Option 10 repair concept is to replace all concrete in all bays above elevation 150 ft, except Bay 3-4, and install radial anchors below elevation 150 ft. On 24 May 2012, Progress Energy selected URS to complete the design and construction planning effort, should the decision be made to repair the facility. Progress Energy and its design subcontractors have made progress in analyzing the structure and developing a methodology to repair the facility. ZAPATA's objective was to conduct an independent, third party review of the engineering and construction plan developed by Progress Energy and URS. Throughout ZAPATA's review process, personnel at Crystal River representing both Progress and URS have been responsive in providing ZAPATA with information essential to this review. The CR3 restoration project is ongoing, and ZAPATA's review and this report represent a perspective based upon the project status as of 1 August 2012.

ZAPATA teamed with industry subject matter experts (SMEs) from Tetra Tech, Inc., High Bridge Associates, Weidlinger Associates, and Dywidag Systems International (DSI), to provide a broad spectrum of capabilities and experience essential to completing this review. Major areas reviewed by ZAPATA include technical feasibility and construction methodology, cost and schedule, and licensing. ZAPATA's Team developed a risk register incorporating risks identified by Progress Energy, Bechtel, URS, Duke Energy, and the ZAPATA Team members.

SUMMARY OF FINDINGS

The scope of work proposed by URS is feasible, but there are risks associated with the technical approach, construction methodology, scheduling, and licensing. Those risks have cost implications that make it problematic to project an actual construction cost.

Top Risks identified in this assessment include:

- Congestion in the work area
- Project management
- Potential damage to the dome
    - Detensioning/Retensioning of the dome may have License Amendment Request (LAR) implications
- Bay radial pinning activities
- Additional cracking or delamination

A. TECHNICAL FEASIBILITY

The URS proposal to repair the containment structure appears to be constructible and feasible based on the engineering work performed to date. There remain, however, several areas of concern which have not been addressed. ZAPATA reviewed engineering calculations, reports, drawings, and finite element models as well as conducted interviews with Progress and URS engineers to gain a thorough understanding of the design and construction methodology. Based upon the URS bid proposal and other materials reviewed, we have the following concerns related to modeling, engineering, and material properties:

1. The global 3-D Finite Element (FE) model uses shell elements, and, therefore, is unable to predict radial stress in the walls and the dome. URS's localized models show radial stresses may exceed allowable values and initiate cracking. Other factors, including ovalling of the structure and the interaction of vertical and radial stresses, have not been evaluated for their potential contribution to radial tension demand. Our concern is the repair design's ability to withstand radial tension beyond what is anticipated. Under-predicting stress could produce a design that is not compliant with applicable codes (Final Safety Analysis Report and Design Basis) which would put the licensing basis at risk.

2. URS performed calculations to quantify how the proposed repair activities will affect the dome. Although the dome is performing as designed, there is distributed laminar cracking. Laminar cracking is a condition where cracks exist on planes parallel to the surface of the dome yet the structure still behaves compositely. The URS FE model has shown that certain stages of construction can cause stresses and/or changes in stress to exceed desirable limits. From the evidence presented, we are not certain whether or not the dome will exceed the code allowable compressive stress in concrete during the repair process. URS is

continuing to refine their model to determine whether or not the dome must be partially de-tensioned during construction to limit compressive stresses. It should be noted that changing dome tension might include the dome as part of the repair plan; this would subject the dome condition to NRC scrutiny.

3. If damage were to occur to the dome during bay repair, it may expose the project to additional licensing risk and NRC scrutiny. The CR3 containment dome has unique regulatory treatment that goes back to the original design and the repairs made in 1976 after the discovery of the delamination that occurred during the original construction. Minor repairs to the dome that do not challenge the previous licensing basis would likely fall within the 50.59 nuclear safety evaluation process. More significant repairs would challenge the limits of the 50.59 process. A LAR would then require the use of modern analysis tools (ANSYS and others) in development of the engineering packages. This may lead the NRC to question the condition of the dome concrete, if the dome were damaged during restoration work. In the event of a need to repair the dome, it may become necessary to replace it in order to obtain NRC approval. Dome replacement carries with it very high costs and schedule implications.

4. Concrete not identified for replacement (i.e., walls outside the current repair scope, buttresses, and the dome) may be subject to stresses during construction that could cause cracking or delamination. Condition assessments to date may not have revealed all the damage that exists in the structure. Additionally, the reinforcement in the buttresses limits the effectiveness of performing non-destructive testing, therefore the extent of cracking in the buttresses is unknown. De-tensioning of the structure is likely to reveal cracks in the walls that will require repair. The URS approach to the facility repair accepts the possibility of additional cracking during repair; however, this additional concrete replacement is not included in the URS estimate. Concrete repairs are included in the ZAPATA risk register.

5. Material properties in the model are code-default values. The concrete modulus of elasticity from field tests differs by as much as 21% from the code values. The choice of modulus of elasticity affects the displacements and/or stress distributions predicted by the FE model. Preliminary comparisons between the current URS FE model and the 1976 Structural Integrity Test (SIT) data, however, show that using code-default values produces reasonable estimates of deflection. This lends support to URS's choice of material parameters. There remains a concern, however, about the influence of actual material properties on conclusions drawn from the FE model. In particular, the

choice of modulus could, in some instances, change the results of code checks which are now used to show the repair complies with applicable code requirements and thus put the design of this containment at risk of non-compliance with its basis.

6. Foundation response is not considered in the model. The URS FE model assumes the foundation materials to be infinitely stiff. This assumption limits the model's ability to predict the settlement/rebound of the containment structure during the different phases of construction. We understand that URS intends to develop another FE model to incorporate foundation stiffness. Modeling the foundation would provide important information that could provide insight into the behavior of the structure. The foundation settlement/rebound during the containment construction will have an impact on connected mechanical systems, such as the fuel transfer tubes and piping. Inaccurate predictions of building movement could lead to damage to existing piping. The settlement/rebound of the foundation may affect the stress distribution in the containment structure, especially in the lower portion of the containment walls and basemat slab.

7. The interface between new and old concrete is modeled as a monolithic joint. Shrinkage in new concrete will begin to occur immediately after the concrete has been placed; the existing concrete has already experienced its anticipated shrinkage, and, therefore, there will be a differential across this boundary. Thus, some minor cracking at the interface might develop during concrete curing. This could affect local stress distributions predicted by the FE model. Discussions between Progress and URS are ongoing about how best to address load transfer at the interface. Improper design of the construction joint could lead to cracking at a future date.

B. CONSTRUCTION METHODOLOGY

ZAPATA reviewed the construction methodology of the proposed containment repair by URS. We were not charged with assessing the demolition or construction method or sequence proposed by URS, but our objective was to review the details of the proposed process to determine the likelihood of success and identify any potential problems. Construction methodology documentation was limited, and for the most part, provided only a general overview of the planned methodology. At the time of this report, Progress Energy had focused most of their resources on addressing the engineering issues related to the restoration of the containment structure and are just now starting to devote significant time and effort toward construction planning.

Congestion in the Work Area

The repair areas below the rooflines and within the surrounding buildings will be on the critical path for the project. These tasks are labor intensive and compounded with extremely congested, restrictive, and elevated work areas. Tendon de-tensioning and removal will require additional specialty rigging and appurtenances. Concrete demolition of the containment wall within these congested areas of the containment structure will be completed by mechanical means with personnel using jackhammers and hydraulic splitters as removal methods. Control of foreign materials and equipment protection will be paramount during the repair tasks to ensure the operating environment and operating components continue to maintain their design basis tasks both during and after repair completion. The details of this first-of-a-kind (FOAK) project effort were not evident in the available construction documentation.

Bay Radial Pinning Activities

It is possible that the construction sequence, including re-tensioning, could initiate cracking and delamination in the walls outside the current repair scope. The risk of cracks or delamination during re-tensioning can be mitigated by installing radial pins. Although URS intends to install two #6 rebar for every nine square feet, there is significant latitude in their proposal to place pins only where interferences do not exist for either the pin or the equipment to install the pin. Core drilling and installation of pins pose installation and logistical challenges. The design for pin placement is not yet advanced enough to show locations of each pin. Furthermore, URS does not intend to install pins from building elevation 103 feet to 110 feet which leaves a band of concrete absent of radial reinforcement around the containment. The flexibility not to install pins in a fixed pattern provides a benefit to the cost and schedule, but may leave large areas without radial reinforcement, thereby increasing risk of cracking and delamination. The view that only some areas require pinning runs contrary to the goal of minimizing the risk of delamination.

Project Management

Industry project management practice is to sequence planning, the detailed engineering, and then construction activities. Progress has chosen to focus on engineering first in order to determine the feasibility of the CR3 restoration. This approach intentionally delayed planning activities until the technical feasibility was established. The result of this change in sequence is a lack of detailed planning at this time. Detailed project and construction planning is in development for this multi-billion dollar nuclear restoration project. Progress stated the detailed project planning work and documents expected include:

- Resource-loaded schedules
- Work Breakdown Structure (WBS) and Dictionary
- Construction Management Plan or equivalent

Progress maintains that once given approval to begin construction, repair work can begin within three months. Given the level of detail in the current planning documents, dated 22 February 2012 and 6 July 2012, we believe the planning required for a project of this size and complexity would take six to nine months for a fully resourced project team to complete an integrated resource-loaded schedule, develop a detailed Work Breakdown Structure (WBS), and complete construction planning before starting actual construction work.

C. COST AND SCHEDULE

ZAPATA reviewed available documentation for the estimated cost and schedule for the CR3 containment restoration. These data assume that the restoration technical approach is completed successfully and no further significant dome or bay concrete cracking and delamination occurs during tendon de-tensioning or re-tensioning. The estimates include the cost already expended for the Bay 3-4 repair.

A summary of ZAPATA's overall conclusions regarding cost is presented below:

- Progress 2011 Preliminary Composite Information –The total EPC and Owner's Preliminary Composite cost is $1.941 billion. This includes contingency and management reserve of $603.6 million. The schedule duration is 25 months. After ZAPATA received the preliminary cost information, Progress later informed us that they did not consider the information complete, and it had not been reviewed by their management. The Preliminary Composite Information, however, contained useful information such as project milestones and major activities that we used in developing our independent estimate.

- URS Bid –The total EPC and Owner's cost for the URS bid is $1.55 billion. This includes contingency and management reserve of $[redacted] million. The schedule duration is 31 months.

- ZAPATA Assessment –The total EPC and Owner's cost for the project is $1.49 billion. This includes contingency and management reserve of $539.5 million. The schedule duration is 35 months.

ZAPATA prepared a rough order of magnitude cost estimate for a scenario based on complete replacement of walls down to the 95 foot elevation and replacement of the dome as the scope of work for the restoration project. The buttresses and ring girder would remain intact and no radial pinning would be required, as all remaining original concrete in the walls would be demolished. The cost for complete replacement of the walls and dome is $2.44 billion including a management reserve amount of $631.4 million. The project duration is 60 months, without contingency.

ZAPATA's assessment assumes the repair method outlined by Progress Energy is not necessarily the worst case scenario. A worst case scenario, including lower bay and dome concrete replacement, was developed assuming delamination occurs at the conclusion of the Progress repair work.

- Should the worst case scenario develop, dome and lower wall replacement is estimated to cost an additional $1.94 billion over 61 months, including a contingency of $446.9 million. Replacement of the dome alone is estimated to cost an additional $575 million over 27 months, including a contingency of $114.9 million. Note that the risks associated with complete replacement of the dome and replacement of the walls not in the restoration scope are not currently in our risk register. Monte Carlo simulations were performed separately for this scenario to develop schedule, cost, and contingency management forecasts.

- The worst case scenario then results in a total project cost of $3.43 billion and an estimated duration of 96 months, including a contingency of $986.5 million. This figure is arrived at by adding the ZAPATA assessment ($1.49 billion) to the worst case additional repair cost ($1.94 billion).

D. LICENSING

ZAPATA assessed the potential impact of licensing risks associated with the CR3 Containment Restoration project as described below and in the following subsections. In this assessment, licensing risk is defined as "any potential issue or change, which is the result of or can lead to an NRC concern and affect the outage duration and restart." In order to assess potential licensing risks, we have divided them into two major categories:

- Licensing Risks Associated with Containment Repairs
- Licensing Risks *Not* Associated with Containment Repairs

The first category represents the "identified risks," which are associated with the repair and are known to date. The second category represents "potential other risks."

We further subdivided the licensing risks associated with containment restoration into the three possible types of activities. These are changes requiring NRC review, changes not requiring NRC review, and maintenance activities (no change in design). They were characterized as follows:

- License Amendment Request
- Design Changes under 10 CFR 50.59
- Maintenance Activities

ZAPATA reviewed the licensing issues identified above, and assessed the risks based on a review of available CR3 documents, discussions with CR3 personnel as needed, and the licensing experience of the assessors.

Appendix D contains a full discussion of licensing issues. A brief discussion of the top licensing risks is presented here.

- Incompleteness of LAR - The potential for the LAR being considered incomplete is much more likely than the LAR being disapproved outright. Not including the planned reduction in tendon prestress is the most likely basis for the LAR to be deemed incomplete. The repaired containment post-tensioning system is scoped to have a prestress return-to-service tendon tension less than that specified in the Final Safety Analysis Report. The decreased tension is beneficial because it decreases the possibility of containment delamination and reduces post-tension levels to those similar to later generation containment designs. At this point, the 10 CFR 50.59 screening has not taken place, and the LAR has not been prepared; therefore, the exact content of the LAR is unknown. Progress believes the reduction in tendon prestress does not qualify for inclusion in the LAR. The ZAPATA Team disagrees with this determination and believes that the reduction in tension should be included in the LAR. Should the NRC also disagree, and the LAR be judged incomplete, a delay in approval would result. The length of the delay would depend on the significance of the omission. We estimate the NRC review delay to be three to six months.

- Disapproval of Reduction in Tendon Prestress - The repaired containment post-tensioning system may have a reduced prestress return-to-service tendon tension from that specified in the current FSAR and design calculations. This approach will reduce the possibility of containment delamination. URS proposes to decrease the prestress to a value that would reduce the end-of-life (EOL) prestress forces in the hoop and vertical tendons by 12% and 10%, respectively. If the reduction in prestress levels is included in the LAR, it is unlikely to be disapproved because similar levels of prestress have been approved by the NRC for prestressed concrete containments, and all code requirements will be met. However, a delay in schedule would result if the tendon prestress reduction were disapproved and potentially increase the risk for further delamination.

- Interference Replacement not Like-for-Like - The equipment that is removed will be the same equipment that is reinstalled. It is expected that a small number of interferences will not be able to be reinstalled due to damage caused during removal, age-related failures, or equipment configuration issues; these items will have to be replaced with new equipment. The like-for-like reinstallation of equipment is considered a maintenance activity, but any new item replacements will need to be screened and/or evaluated as 10 CFR 50.59 activities. There is a risk that unforeseen circumstances will force unexpected replacement of interferences required to be addressed in the 10 CFR 50.59 process.

  URS recognizes the possibility that new equipment may need to be installed to replace damaged items or items that otherwise cannot be reinstalled following removal of the interferences. Based on a review of the plant licensing basis, the URS proposal, and interviews with plant personnel, the possibility of needing to install new equipment to replace interferences is being adequately addressed from a licensing perspective. However, delays could result from appropriate engineering justification and potential equipment procurement.

- Permanent Radial Anchors - URS states that supplemental radial reinforcing steel is not required to meet the design basis lateral and thermal design loading, and, that the inclusion of the radial reinforcing bars will increase the margin of safety against delamination. The use of these permanent radial anchors presents a licensing risk, if they are not adequately addressed through the 10 CFR 50.59 process. URS expects to evaluate the concrete permanent radial pins in the 10 CFR 50.59 evaluation. The permanent radial pins will not be credited to meet the design basis; however, a delay could result, if the design of the pins is not approved through the 10 CFR 50.59 process.

CLOSING

This report represents our findings using the data provided during the short duration of the CR3 Containment Restoration project review period. As the CR3 project is an ongoing activity, the most up-to-date information may not have been available for our review, and, therefore, not reflected in our observations. ZAPATA was only able to review data provided to us. There may be additional information regarding the proposed CR3 restoration of which we were unaware. It is also important to note that ZAPATA's efforts have been limited to the review of engineering performed by others.