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# Light Water Reactor Sustainability Program

# Business Case Analysis for Digital Safety-Related Instrumentation & Control System Modernizations

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Light Water Reactor Sustainability Program

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# SUMMARY

The commercial nuclear sector faces unprecedented financial challenges driven by low natural gas prices and subsidized renewables in a marketplace that does not reward carbon-free baseload capacity. These circumstances, along with increasingly antiquated labor-centric operating models and analog technology, have forced the premature closure of multiple nuclear facilities and placed a much larger population of nuclear power stations at risk. Nuclear plant economic survival in current and forecasted market conditions requires an efficient and technology-centric operating model that harvests the native efficiencies of advanced technology. This is analogous to transformations in nearly every other industry. In light of previous industry experience in modernizing safety Instrumentation and Controls (I&C) systems, nuclear utilities are reluctant to pursue these upgrades due to uncertainty in licensing and cost.

Historical licensing barriers have largely precluded the modernization of nuclear plant first-echelon safety systems to support this transformation. These barriers have now been largely addressed through collaboration between industry leaders and the Nuclear Regulatory Commission (NRC). These advances enable the modernization of key safety systems through the streamlined license amendment process reflected in Digital Instrumentation and Controls Interim Staff Guidance #06 (DI&C-ISG-06), Revision 2, “Licensing Process” [Reference 1].

While regulatory advances have improved the environment for modernizing safety systems, the industry has remained reluctant to perform such I&C upgrades because of perceived regulatory risks associated with being the first adopter of the DI&C-ISG-06, Revision 2 process for a major critical safety system. Light Water Reactor Sustainability (LWRS) Program research report INL/LTD-20-58490, *Vendor-Independent Design Requirements for a Boiling Water Reactor Safety System Upgrade*, [Reference 2] was developed in part to help address this concern.

The industry’s reluctance to modernize safety I&C systems is further complicated due to uncertainty in cost. As an industry example, a safety I&C system upgrade performed by a utility at one of their nuclear stations in the 2000s. The upgrade took more than 10 years to complete and cost more than $200 million, which was much greater than the expected duration and cost for the project. The final upgrade cost represented nearly 10% of the original capital costs of a unit. Although ultimately completed, this event resulted in widespread industry skepticism concerning the predictability of costs and the regulatory approval process for such upgrades. Two decades later, the chilling effect of this notable example and the conditions that contributed to it still impede nuclear plant modernization.

This LWRS research seeks to help break the impasse precluding digital safety system upgrades by generating and demonstrating a process and related business case tool to enable a Business Case Analysis (BCA). The purpose of a BCA is to show such upgrades can be economically justified.

This BCA methodology first systematically establishes a forecast of expected lifecycle costs for I&C identified for upgrade by:

- Definitively bounding the scope of current I&C systems envisioned for upgrade.
- Collecting historical labor and material usage data that bound cost contributors related to the systems to be upgraded.
- Synthesizing and analyzing the data to establish lifecycle cost forecasts for the current systems.

In collaboration with engineers familiar with the attributes of the digital equipment to be used in the upgrade and how it is envisioned to be applied, cost savings categories and expected savings in those categories are then identified and applied using the analysis tools developed for this purpose. The result is an estimated Net Present Value (NPV) of savings enabled by the upgrade. This includes both direct cost savings (e.g., surveillance labor costs) as well as cost avoidance items (e.g., inventory carrying costs). Finally, when utility-provided digital upgrade cost estimates are included, the resultant BCA provides an NPV for the upgrade project.

Development of a useful BCA methodology requires a real-world basis. With the cooperation of Exelon Generation ("Owner"), an Exelon-owned two-unit BWR Station ("Station") was used as the foundation for this research. Exelon is pursuing a digital upgrade of current, first-echelon, safety-related I&C systems at these units, including the following:

- Reactor Protection System (RPS)
- Nuclear Steam Supply Shutoff System (N4S)
- Emergency Core Cooling Systems (ECCS)
- Anticipated Transient Without Scram (ATWS) Mitigation System.

INL/LTD-20-58490 [Reference 2] provides detail for the design concepts for this upgrade. Initial BCA results based on those design concepts support a compelling case for upgrading these systems. Collected data for this effort was also independently used as an input to a business case tool developed by the Electric Power Research Institute (EPRI)[1], which produced a similar result.

The BCA specific results for the reference Exelon units are considered proprietary to Exelon and are provided in a limited distribution version of this research product. For this public version, financial data have been altered to protect the Owner's proprietary information. As presented herein, BCA results are intended to be illustrative and representative in scale of benefits and are not intended to provide material data utilized in Exelon's internal project cost-benefit analysis. The ultimate purpose of this public, non-proprietary version is to communicate the process and related business case tool to enable similar BCA for digital upgrades throughout the industry. It is expected that this methodology can be abstracted and used for nearly any system upgrade.

This research also includes a presentation (developed in Microsoft PowerPoint) of the benefits of the envisioned digital I&C safety system upgrades to further enable the generation of a compelling case for upgrades to both plant and utility management.

The BCA methodology was produced by ScottMadden, Inc., in collaboration with LWRS researchers. Key support of this effort was also provided by subject matter experts (SMEs) from MPR Associates, Inc., and Exelon's Station. The LWRS Program appreciates the research support provided by Exelon Generation. This research report and the associated appendices make no commitments for Exelon Generation.

[1] This tool and supporting documents can be found here: https://www.epri.com/research/products/000000003002019454

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# ACRONYMS

| | |
|---|---|
| ACO | Avoided Cost of Obsolescence |
| ADS | Automatic Depressurization System |
| ATWS | Anticipated Transient Without Scram |
| BCAM | Business Case Analysis Model |
| BWR | Boiling Water Reactor |
| CA | Corrective Action |
| CAGR | Compound Annual Growth Rate |
| CAP | Corrective Action Program |
| CATID | Catalog Identification Number |
| CM | Corrective Maintenance |
| CS | Core Spray |
| CFR | Code of Federal Regulations |
| CoC | Cost of Capital |
| CMO | Component Maintenance |
| CY | Chemistry |
| DI&C-ISG-06 | Digital Instrumentation and Controls Interim Staff Guidance #06 |
| DAS | Diverse Actuation System (function in a DCS) |
| DCS | Distributed Control System |
| DKT | Display(s), Keyboard, and Trackball integrated Human System Interface |
| EC | Engineering Change |
| ECCS | Emergency Core Cooling Systems |
| EN | Engineering |
| EO | Equipment Operator |
| EPRI | Electric Power Research Institute |
| FA | Functional Area |
| FCF | Future Cash Flows |
| FTE | Full Time Employee |
| HPCI | High Pressure Coolant Injection |
| HSI | Human System Interfaces |
| HVAC | Heating, Ventilation, and Air Conditioning |
| I&C | Instrumentation and Controls |
| IT | Information Technology |
| LAR | License Amendment Request |
| LDS | Leak Detection System |
| LPCI | Low Pressure Coolant Injection – mode of RHR |
| LWR | Light Water Reactor |
| LWRS | Light Water Reactor Sustainability (Program) |
| MA | Maintenance |

| | |
|---|---|
| MCR | Main Control Room |
| N4S | Nuclear Steam Supply Shutoff System |
| NRC | Nuclear Regulatory Commission (United States) |
| NUMAC | Nuclear Measurement Analysis and Control (a General Electric - Hitachi control system product) |
| O&M | Operating and Maintenance |
| OLM | Online Monitoring |
| OP | Operations |
| PM | Preventive Maintenance |
| PMI | Planned Maintenance Item |
| PMID | Planned Maintenance (item) Identifier |
| PPS | Plant Protection System |
| PV | Present Value |
| PWR | Pressurized Water Reactor |
| RCIC | Reactor Core Isolation Cooling |
| RCPB | Reactor Coolant Pressure Boundary |
| RHR | Residual Heat Removal |
| RO | Reactor Operator |
| ROC | Return on Capital |
| RP | Radiation Protection |
| RPS | Reactor Protection System |
| SME | Subject Matter Expert |
| SRO | Senior Reactor Operator |
| ST | Surveillance Test |
| TR | Training |
| WM | Work Management |
| WMS | Work Management System |
| WO | Work Order |

# BUSINESS CASE ANALYSIS FOR DIGITAL SAFETY-RELATED INSTRUMENTATION & CONTROL SYSTEM MODERNIZATIONS

## 1. Introduction

First-echelon safety systems currently installed in operating nuclear power plants have historically performed their intended function admirably. However, most are of the original plant vintage and based on decades-old technology. As such, these safety systems are increasingly less supportable and more maintenance intensive than modern digital alternatives. Parts for current systems are increasingly difficult and costly to obtain. Expertise to maintain these older analog (and in some cases, first-generation digital) systems is waning. Costs associated with operating and maintaining older systems are also rising rapidly. System costs for industry-typical, like-for-like replacements can rival those for newer digital system designs which provide much more capability. Making additional investments on obsolete systems or providing like-for-like digital replacements that perform the same function as the original systems provides no opportunity for employing advanced digital technology capabilities to lower plant costs or improve plant performance.

This research product is intended to illustrate for utilities considering a digital modernization of I&C systems a methodology to evaluate cross-functional labor and material benefits and conduct a financial analysis as part of development of the overall business case for digital modernizations. The objectives of this research product are to:

- Provide a “bottom-up” approach to:
  - Establish labor and material costs for the current systems within the defined I&C upgrade scope
  - Identify expected labor and material benefits enabled by the upgrade design concept
  - Validate the expected benefits with Subject Matter Experts (SMEs)
- Demonstrate a methodology utilized to perform a detailed financial analysis, including the following:
  - Estimation of annual benefits related to organizational workload reductions for both online and outage work
  - Estimation of annual benefits related to materials and inventory expenditures
  - Valuation of avoided lifecycle costs associated with escalation of material expenditures
  - Valuation of the modernization over the lifecycle of the Station
- Illustrate the scale of benefits that can be expected from a modernization of safety-related I&C systems at a two-unit Boiling Water Reactor (BWR) nuclear power station
- Offer example worksheets and templates to support a business case analysis of similar efforts by other utilities
- Provide lessons learned and opportunities for utilities that might subsequently implement a similar digital modernization effort

## 1.1 Project Development Approach

A cross-functional team (“Project Team”) was assembled to develop the proposed Digital Safety-Related I&C System Modernization (“Project”). The Project Team included representatives from both LWRS and the Owner. LWRS representation consisted of a principal investigator, a research engineer, contracted conceptual and design engineering, and contracted management consulting to support the BCA. Owner representation consisted of central engineering and project management resources as well as current and former station system and I&C engineering. The Owner also made available SMEs from operations, maintenance, work management, training, supply chain, and warehousing, as well as representatives from licensing, training, and programs such as the Corrective Action Program (CAP).

At the outset of work, the Project Team drafted a development plan for the Project to coordinate various overlapping and interdependent activities illustrated in Figure 1 below.

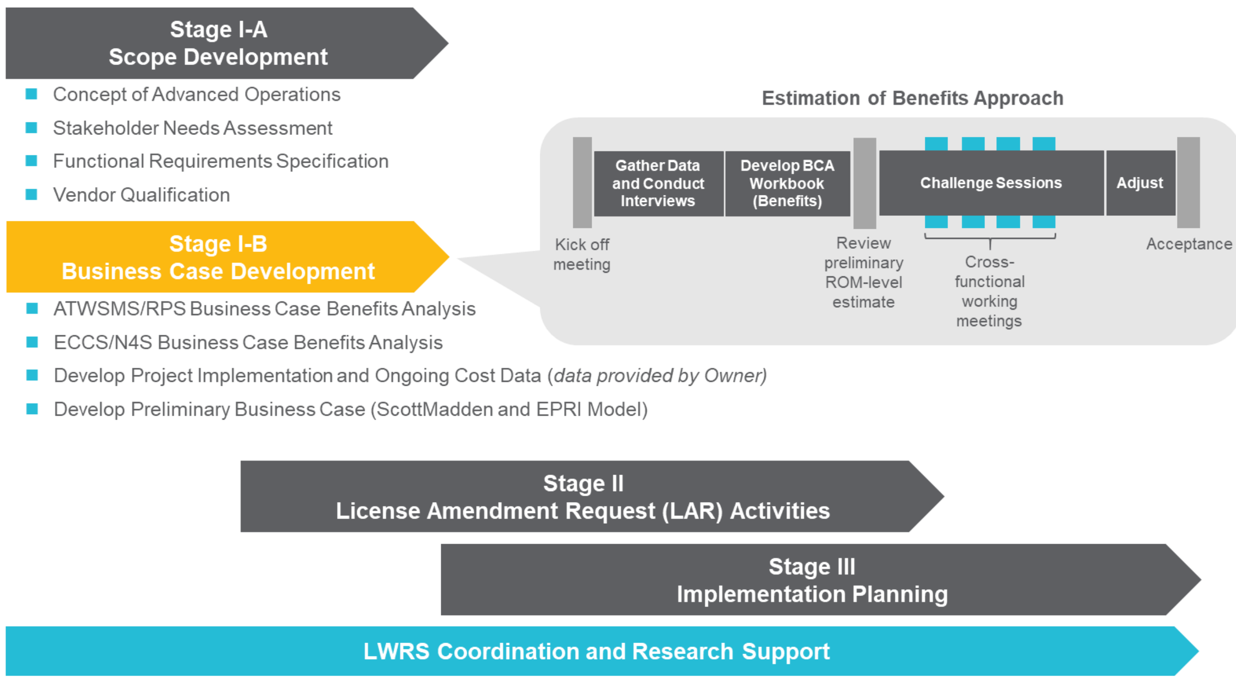


Figure 1: High-level Project development plan.

The high-level plan is broken down into stages:

- Stage I: (a) Scope Development and (b) Business Case Development
- Stage II: License Amendment Request (LAR) Activities
- Stage III: Implementation Planning.

The three stages are interdependent and overlap each other in timing. The focus of this research involves activities highlighted in Stages I-B.

## 1.2 Expected Project Outcomes

While Project efforts will undoubtedly support this pilot implementation, products generated by the Project will be invaluable in enabling similar upgrades in the U.S. Light Water Reactor (LWR) fleet. Project engineering deliverables, including requirements, specifications, traceability matrices, completed test procedures, drawings, calculations, Engineering Change (EC) packages, platform configuration work instructions, simulator upgrade documentation, etc., will be made available by the Owner to the U.S. LWR fleet. This will provide a technical roadmap for performing similar LWR upgrades. Utilities with BWRs are expected to be able to directly benefit by essentially performing a “delta analysis” of Project engineering deliverables when upgrading similar systems (RPS, N4S, ECCS to a Plant Protection System [PPS] and migrating their ATWS Mitigation System [or non-safety ATWS, which performs a similar function] to a non-safety related Distributed Control System [DCS]). It is expected that many BWR utilities would also use the same vendor selected by the Owner to enable a “design-once-build-many” strategy. Pressurized Water Reactors (PWRs) are also expected to benefit by mirroring their engineering efforts to follow the roadmap established for BWRs.

Project licensing deliverables will provide a regulatory roadmap for performing similar LWR upgrades. The Alternate Review Process contained in DI&C-ISG-06, Revision 2, will be fully exercised by the Project, resulting in an approved LAR and fully dispositioned requests for additional information from the regulator. Any PPS advanced features not included in the initial NRC Safety Evaluation Report for the platform selected by the Owner (e.g., automated diagnostics as a replacement for manual surveillance tests) will be included in the Station's LAR, which will be incorporated and accepted in the NRC's Safety Evaluation Report for the upgrade. Again, utilities with BWRs are expected to directly leverage these products as a foundation for their LAR submittals for similar upgrades. PWRs should also benefit by mirroring their licensing efforts to follow the roadmap established for BWRs.

Project management deliverables will also provide a roadmap to guide project planning and execution for similar LWR upgrades. Items such as the Station work breakdown structure, organizational structure, detailed Project schedules, and risk register can be leveraged. While Owner business-sensitive information to obtain Project authorization will not be directly shared with industry, the processes (which are common with industry) and lessons learned to create it will be shared by the Owner.

BCA specific results for the reference Owner units performed as part of this research provide specific data used to support project management activities and ultimately supports management decision-making by the Owner regarding Project authorization. This non-proprietary version communicates the process and related business case tool to enable similar BCA for digital upgrades throughout the industry. It is expected that this methodology can be abstracted and used for nearly any system upgrade.

## 1.3 Advanced Concept of Operations

Up to now, there has been no roadmap for performing a large-scale digital transformation of currently operating nuclear plants to extend their technical longevity, while at the same time reducing their operating and maintenance (O&M) costs.

The LWRS plant modernization pathway, with input from Owner, has developed a design concept for first-echelon BWR safety system I&C upgrades as a key enabler for a larger Advanced Concept of Operations that moves an existing plant from a labor-centric analog domain to a technology-centric digital domain. This is illustrated in Figure 2Figure 2 below.

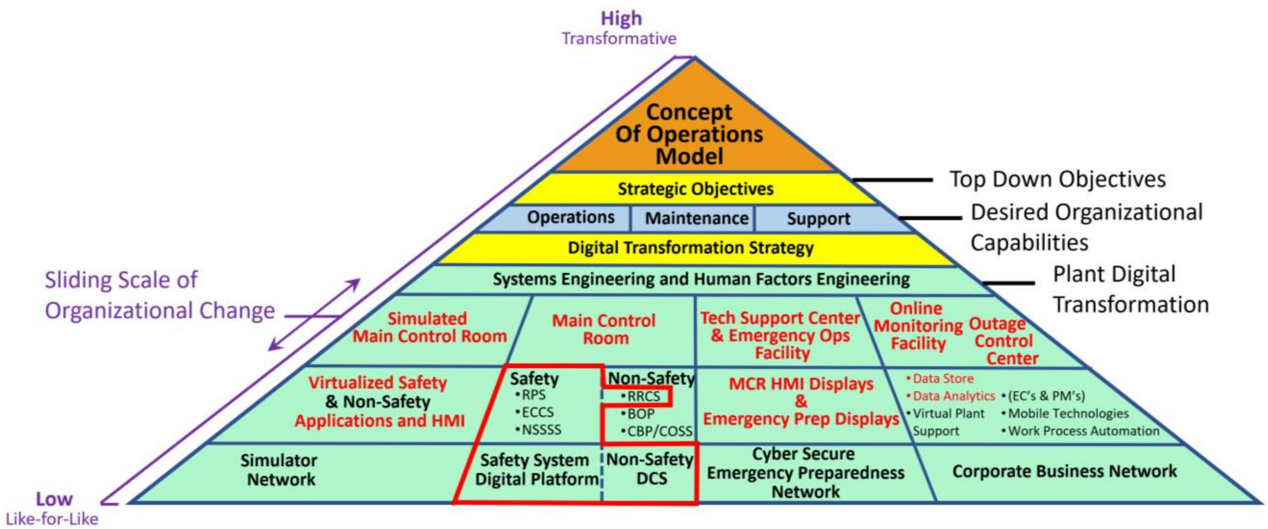


Figure 2: Safety-related I&C enables Advanced Concept of Operations functions.

The Advanced Concept of Operations model as establishes strategic objectives and constraints for all plant protection, control, and business functions as an integrated set (shown in green above). This model promotes a business-driven digital transformation strategy that reformulates the traditional labor-centric nuclear power plant operating model to one that is technology centric. This supports a smaller onsite staff footprint, while increasing safety, reliability, and situational awareness. This also improves focus on daily plant operations.

## 1.4 Scope of Research

The research scope of this phase of the digital transformation strategy for a BWR is outlined in red in Figure 2 above, and includes:

1. A PPS platform and application functional requirements baseline. The envisioned PPS is a common, safety-related platform that will implement the functions of the following BWR systems as applications:
    - Reactor Protection System (RPS)
    - Nuclear Steam Supply Shutoff System (N4S)
    - Emergency Core Cooling Systems (ECCS)

    The PPS is expected to be expandable to support eventual migration of other safety-related functions in the unit, within the hardware capabilities of the utility selected platform. To support the broader regulatory objectives and control costs/risks, the utility is also expected to select a platform with a licensing topical report pre-approved by the NRC.

2. A non-safety related platform and application requirements baseline for the existing safety-related ATWS Mitigation System. In accordance with 10 CFR 50.62, "Requirements for reduction of risk from anticipated transients without scram (ATWS) events for light-water-cooled nuclear power plants" [Reference 3], the ATWS Mitigation System must remain fully independent and diverse from the PPS but need not be constructed of safety-related components. Consequently, the ATWS Mitigation System is expected to be upgraded using a non-safety related DCS.

Developing a design concept for these first-echelon BWR safety system I&C upgrades and a path to obtain approval of an associated LAR are key enablers for the holistic approach of the envisioned digital transformation. LWRS research report INL/LTD-20-58490, "Vendor-Independent Design Requirements for a Boiling Water Reactor Safety System Upgrade," was developed to provide that design concept, along with supporting a path for LAR approval.

Additionally, the design concept must be shown to produce economic benefits that support the continued profitable operation of the upgraded units. This research report captures the process and related business case tool to enable such a BCA. This BCA methodology (elaborated in Section 3) was generated in conjunction with upgrades described in INL/LTD-20-58490 to show that the scoped upgrades at the Station can be economically justified. Features of the larger digital infrastructure enabled or leveraged by this upgrade within the larger Advanced Concept of Operations model are generally identified with red text inFigure 2. Specific features identified in the design concept leveraged to support this BCA are identified in Section 2.2.

Initial related economic research evaluations of implementing the PPS along with its associated applications, as well as migrating the ATWS Mitigation System to a non-safety-related DCS, provide a compelling justification to support these upgrades.

## 1.5 Economies of Scale

The overall approach and the selected scope described in this research product exploits economies of scale. By including all identified safety-related systems in the scope as part of the Advanced Concept of Operations, as opposed to approaching each system individually, the Project Team was able to propose a unifying architecture in a common system platform. This approach has several advantages including those listed below:

- Reduced overall installation costs compared to approaching systems separately
- Common hardware and replacement components
- Reduction of redundant components and field instruments needed to operate separate systems.

Certain benefits identified as part of this research are dependent on this combined approach. For example, panels that house much of the I&C components for the safety-related systems are housed in a separate equipment room. Operators currently perform shift surveillances and record instrument readouts from analog gages located in this separate room. For a two-unit BWR, this means an operator goes out to the field, manually scribes data, verifies it with a supervisor, and enters it in a computer database where the data can be reviewed by a senior reactor operator, four times per day. The proposed modernization eliminates the need to perform all these activities, but only if all the systems are modernized together.

# 2. Basis of BCA for Proposed Digital Modernization of Safety-Related I&C Systems

Development of a BCA for a system replacement first requires a comprehensive understanding of the system to be replaced as a foundation. The architecture and key features of the proposed digital modernization that enable cost savings and cost avoidance also need to be understood. This information together allows the identification of expected benefits of the proposed digital modernization. This section addresses these basis items for the BCA.

## 2.1 Safety-Related Systems Targeted for Modernization at the Station

### 2.1.1 Description of Existing Reactor Protection System

The primary function of the RPS is to initiate a scram of the reactor through insertion of the control rods in order to:

1. Prevent or limit fuel damage following abnormal operational transients
2. Prevent damage to the Reactor Coolant Pressure Boundary (RCPB) as a result of excessive internal pressure
3. Limit the uncontrolled release of radioactive materials from the fuel assembly or RCPB.

The RPS provides this function by monitoring certain plant parameters and, if one or more parameters exceed a specified limit, the RPS system functions to automatically insert control rods to terminate power production in the core.

### 2.1.2 Description of Existing Nuclear Steam Supply Shutoff System

The N4S initiates the closure of various automatic isolation valves if the monitored system variables exceed pre-established limits. This action limits the loss of coolant from the RCPB and the release of radioactive materials from the RCPB, the primary containment, and the reactor enclosure. The functional requirements associated with the N4S and its interfacing systems necessitate the following:

1. Pipes or vents that penetrate primary containment and communicate directly with the reactor vessel have two isolation valves: one inside primary containment (i.e., inboard) and one outside primary containment (i.e., outboard).
2. Pipes or vents that connect directly to the containment atmosphere and penetrate primary containment have two valves outside containment (i.e., inboard closest to containment and outboard farther away from containment).

### 2.1.3 Description of Existing Emergency Core Cooling System

The ECCS is comprised of independent core cooling systems that ensure the requirements of 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," are satisfied if a breach in the RCPB results in a loss of reactor coolant. The following systems are included in the ECCS, except where noted:

- High-Pressure Coolant Injection (HPCI): The HPCI system provides and maintains an adequate coolant inventory inside the reactor vessel to limit fuel cladding temperatures resulting from postulated small breaks in the RCPB. The HPCI system uses a large steam-driven pump to inject water to the reactor vessel.
- Automatic Depressurization System (ADS): The ADS acts to rapidly reduce reactor pressure in a Loss-of-Coolant Accident (LOCA) in which the HPCI system fails to maintain reactor vessel water level. This depressurization function is executed by simultaneously opening multiple Safety/Relief Valves (SRVs) by the ADS, based on conditions that indicate HPCI cannot maintain reactor water level sufficiently high while the reactor vessel is still pressurized.
- Core Spray (CS): The CS system cools the fuel by spraying water on the core in the event of a LOCA associated with a wide range of pipe break sizes. This function is executed through use of motor-driven pumps along with the requisite piping, valves, and control systems.
- Residual Heat Removal (RHR): The RHR system performs several functions through the use of different operating modes. The Low-Pressure Coolant Injection (LPCI) mode is credited as part of the ECCS. LPCI acts to mitigate the consequences of a large-break LOCA by injecting into the reactor vessel at low reactor pressures. The RHR system also has non-ECCS modes that support containment cooling (suppression pool cooling, containment spray), shutdown cooling for decay heat removal, and other support functions (e.g., fuel pool cooling assist, alternate decay heat removal, and suppression pool level control through a radioactive waste system interface). The RHR system executes this function through use of motor-driven pumps along with the requisite piping, valves, heat exchangers, and control systems.
- Reactor Core Isolation Cooling (RCIC): The RCIC system provides makeup water to the reactor vessel whenever the vessel is isolated from the main condenser and feedwater system. RCIC is not credited as an ECCS system, although RCIC performs similar functions. RCIC executes its safety function in a manner similar to HPCI through use of a steam-driven pump that injects into one of the main feedwater lines associated with the reactor vessel. However, RCIC operates with a much smaller capacity than the HPCI system.

### 2.1.4 Description of Existing ATWS Mitigation System

The ATWS Mitigation System provides a diverse means of shutting down the reactor in the event of an ATWS to satisfy regulatory requirements. The ATWS Mitigation System accomplishes this function by shutting down the reactor at pressures above and reactor water levels below the pressure and level at which the RPS should have scrammed the reactor.

The diverse methods of power reduction and reactor shutdown executed by the ATWS Mitigation System include the following:

- Initiation of Alternate Rod Insertion (ARI) to vent the scram air header and insert control rods
- Stopping the reactor recirculation pump motors by tripping their power supply breakers upon receipt of ATWS indications
- Automatic runback of reactor feedwater pumps to support terminate-and-prevent actions and leverage reactor thermal-hydraulics to reduce power
- Initiation of the Standby Liquid Control System following receipt of ATWS conditions (i.e., reactor at high pressure, low level, and sustained high-power conditions).

## 2.2 Architecture and Key Features of Proposed Digital Modernization of Safety-Related I&C Systems

With the scope of the upgrade fully bounded and lifecycle costs and trends of the existing systems fully understood, an understanding of the capabilities of the upgraded architecture and its features can be leveraged to identify enabled cost savings.

### 2.2.1 Existing and Upgraded Architecture

The existing RPS, N4S, and ECCS are currently implemented as separate systems that execute their safety functions in a segregated manner. Each unit has its own set of these systems at the Station. These systems are largely comprised of analog trip units (channels) and wiring between the trip units and relay logic within the electrical divisions. Each division is responsible for performing voting, time delay, and other logic-based functions. The existing RPS and most of the N4S are installed in four cabinets in an electronics room separate from the Main Control Room (MCR) with additional N4S and all of the ECCS installed in additional cabinets in the same electronics room. The wiring connects channels within an electrical division to the relay logic within that electrical division. A simplified diagram of the existing architecture is shown in Figure 3Figure 3 below.  The N4S and ECCS architectures are similar.

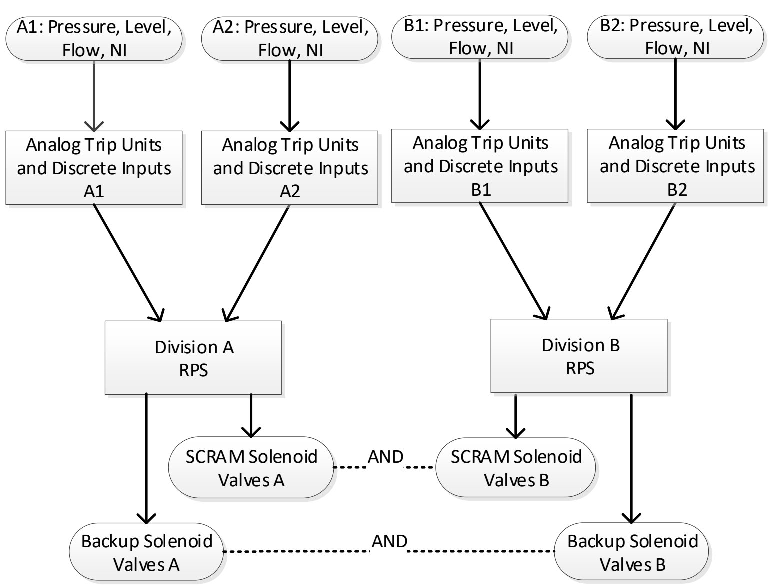


Figure 3: Existing system architecture.

The existing safety-related ATWS Mitigation System makes use of Transistor-Transistor Logic (TTL) in safety-related, redundant processors. The digital ATWS Mitigation System samples analog inputs and implements the ATWS logic in this microprocessor-based system. This obsolete digital equipment is equipped with self-tests and self-diagnostics. Maintenance of this equipment is increasingly difficult, since TTL integrated circuits are no longer widely available.

The existing interface for the RPS, N4S, and ECCS rely on indicator lamps, annunciator windows, meters, and recorders in the MCR. The existing design provides Leak Detection System (LDS) annunciation in the MCR but only provides LDS data displays in the electronics room. Potential steam leaks are detected through the use of several thermocouples routed to General Electric-Hitachi Nuclear Measurement Analysis and Control (NUMAC)s located in the electronics room. If the NUMAC detects a potential steam leak, an alarm is generated in the MCR. To determine the location of the leak, the MCR staff dispatches an equipment operator to the electronics room to read and relay temperatures and status from the NUMAC displays in the electronics room back to the MCR. For channel checks, an operator uses the analog trip unit displays to gather data, since almost none of the data is available in the MCR. Channel comparisons are then performed by hand and reviewed by other operations personnel.

The proposed modernization will focus on the elimination of analog trip units and relay logic for the RPS, N4S, and ECCS. The LDS will be absorbed into the PPS as well. The existing, discrete systems will be replaced with a digital PPS to support a more streamlined architecture and reduce redundant field components and instrumentation as shown in Figure 4 below. This architecture will execute the existing discrete functions performed by the RPS, N4S, and ECCS using a consolidated solution built around a digital platform.

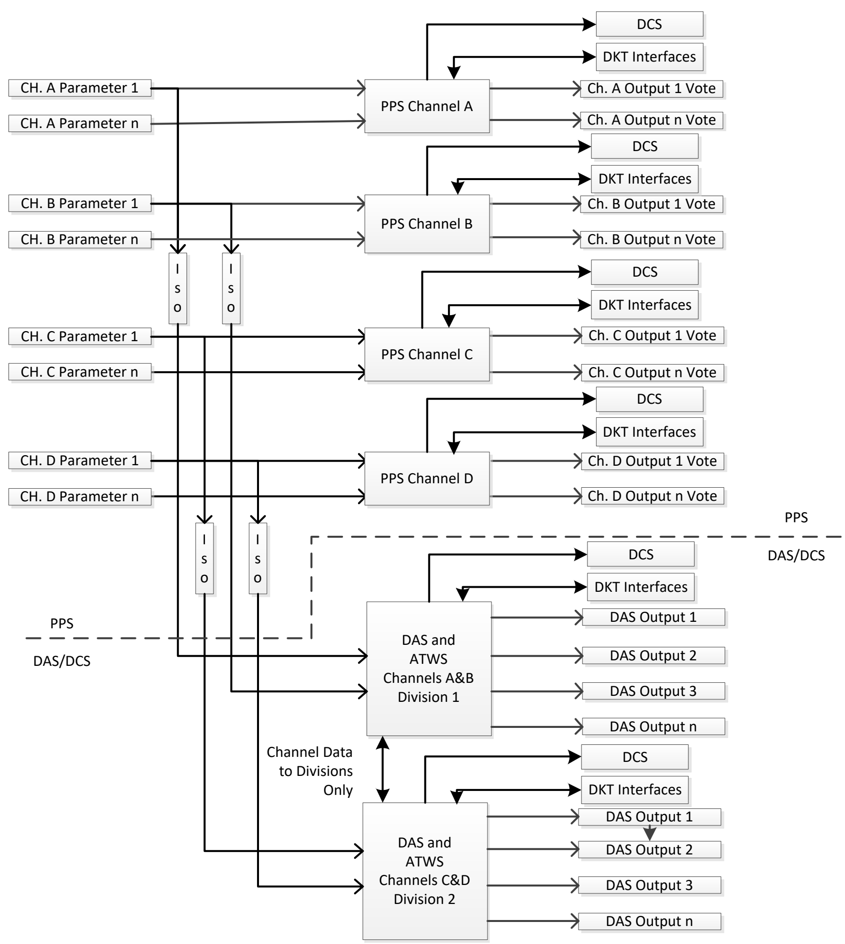

Figure 4: Modernized system architecture.

The proposed modernization will also remove the safety-related ATWS Mitigation System and install a non-safety related ATWS Mitigation System. The modernization may include a Diverse Actuation System (DAS) for the appropriate portions of the RPS, N4S, and ECCS. The need for a separate DAS will be contingent upon the results of a defense-in-depth and diversity analysis to determine whether the PPS is sufficiently hardened against common cause failures.

### 2.2.2 Key Features and Enablers of Quantifiable Project Benefits

The digital modernization effort proposed for this Project relies on several essential enablers that are inherent or specified features of the digital upgrade. These include technology and process enablers. Each enabler conveys various benefits. Quantifiable benefits included in the BCA are described below:

- Self-Diagnostics: Modern digital platforms include self-diagnostic features which are capable of detecting system failures in real time to ensure that I&C systems remain capable of performing their specified functions. I&C faults are annunciated so that plant O&M personnel can take the appropriate action. This enables reduced maintenance and can enable reduction or elimination of time-based surveillance requirements.
- Unidirectional Data Flow: The data obtained by the safety-related platform will be transferred unidirectionally to the non-safety related platform. Software in the non-safety related platform will then compare the data from redundant transmitters, checking that all readings are within an acceptable range defined for each transmitter.
- Application Software: Application software replaces a significant amount of hardware when the digital solution is implemented (~75% of the existing system hardware is eliminated by the proposed upgrade). This enables reductions in maintenance and materials costs associated with the equipment and also increases the versatility of the system as a whole.
- Sensing Instrument Reduction: Legacy I&C systems execute functions in a segregated fashion which often requires separate inputs for the same parameter. Digital platforms have a greater capacity for using a consolidated set of inputs for multiple functions. This permits a reduction in the number of sensing instruments (~75% of existing sensing instruments for the proposed upgrade) and a corresponding reduction in cost associated with these sensing instruments.
- Redundant/Modernized Power Distribution Units: Legacy I&C systems make use of dated power distribution equipment and configurations. Modern digital platforms are capable of operating with more efficient power supply arrangements that require less maintenance.
- Solid-State Electronics: Maximizing the use of solid-state electronics in a proposed digital solution has the effect of minimizing future maintenance and materials costs as these are typically lower than the costs associated with legacy electromechanical equipment (e.g., Agastat relays, HFA relays).
- Lifecycle Support Strategy: Vendor lifecycle support strategies are essential enablers for ensuring that future equipment obsolescence costs do not erode the benefits associated with a digital platform solution.

### 2.2.3 Additional Enablers that Support the Advanced Concept of Operations and Provide Qualitative Financial Benefits

In addition to those items listed in Section 2.2.2 above, that directly contributed to the BCA, there are other technology and process enablers that not only support the Advanced Concept of Operations but also are expected to provide implementation and lifecycle cost savings. While these were not directly incorporated into the BCA, these enablers should be considered as areas where additional financial benefits are likely to be realized. These include:

- Standardized Cyber Security: Ensuring that a proposed digital platform solution has a standardized approach to cyber security limits the downstream actions required for future integration of other functions and minimizes licensing challenges.
- System Integration Capabilities: The ability to leverage new digital system platforms in the future to integrate additional legacy system functions performed by obsolete equipment is essential for implementation of a broader digital modernization strategy at minimum cost.
- Simulator Integration Capabilities: The MCR plant simulator must be modified to support the new digital platforms. Ensuring that a vendor can support these actions, including the potential use of a digital twin, minimizes the costs associated with this required activity. Such efforts are expected to yield additional cost and risk reduction benefits (e.g., using the digital twin as a design tool to develop and test needed changes to the system and its Human System Interface (HSI) or to add expanded functionality).
- Hybrid Interface Capabilities: The digital platform will interface with legacy plant systems for an extended period (and likely for the duration of the plant license in some cases). The ability of new digital platforms to interface with legacy equipment will aid in electronic data collection and analysis, which can be leveraged to enable workload reductions.
- Switched Display, Keyboard, and Trackball (DKT) Concept: This concept minimizes the number of video displays in the MCR while optimizing the Human Factors Engineering that must be performed to support the proposed digital platform solution. It also supports a phased implementation of upgrades with minimum rework between phases. Electronic displays (graphics) once created for presentation on DKTs can be retained and expanded electronically as part of a growing "display library" instead of having to make repeated physical modifications to MCR panels for each incremental change. Additional DKTs are added as necessary to a point where enough exist in the MCR. Beyond this, only the addition of electronic display graphics to the display library is necessary as needs dictate.
- Safety-Related DKTs: Implementation of a hybrid or glass MCR is reliant on the ability to monitor and control the PPS from safety video displays. Use of safety-related DKTs also minimizes the licensing risks associated with using non-safety related HSIs to operate safety-related equipment.

### 2.2.4 Design Feature Selections that Enable Cost Avoidance

In addition to those items listed in Section 2.2.3 above, strategic selection of design features for the PPS and the DCS onto which ATWS Mitigation System functions will be migrated can provide cost avoidance when implementing new systems. While these were not incorporated into the BCA, these design features should be considered to minimize the cost of new system implementations.

- Equipment Fit-Up: The proposed digital platform solution should be selected (if possible) so that it has minimal fit-up issues. This ensures that additional costs are not incurred to support physical installation of the proposed solution into existing cabinet locations.
- Equipment Heat Generation: Minimizing the heat generated by the selected digital platform ensures that existing Heating, Ventilation, and Air Conditioning (HVAC) infrastructure does not need to be reconfigured or modified in any way to support the new digital platform.
- Equivalent or Bounding Seismic Qualification: Selecting a digital solution that satisfies the existing seismic spectra requirements minimizes the costs associated with structural engineering to support implementation of the new solution.

- Minimal Power Supply Requirements: Selecting a digital solution that minimizes power supply requirements ensures that existing plant power supplies (e.g., batteries, inverters) do not have to be reconfigured to support implementation of the new digital solution.
- Comprehensive Factory Acceptance Testing: Effective factory acceptance testing minimizes the downstream work associated with implementation of a proposed digital platform solution.

## 2.3 Description of Expected Benefits of Proposed Digital Modernization of Target Safety-Related I&C Systems

The design concept for the envisioned upgrade as captured in the Functional Requirements Baseline Documents for PPS and ATWS Mitigation System, as well as the PPS LAR Framework Document contained in INL-LTD-20-58490, provide an aggregate solution that goes far beyond a like-for-like replacement. These documents describe capabilities and features enabled by digital technology to reduce acquisition, O&M, and lifecycle costs. This design concept includes features that enable improved plant performance, improved data retention and analysis, and improved HSIs. These features enable a larger, plantwide digital transformation end state that minimizes the plant total cost of ownership. Areas of expected cost reductions enabled by the digital upgrade design concept are described below.

### 2.3.1 Labor Benefits

#### 2.3.1.1 Surveillance and Test Workload Reductions

**Logic System Function Tests**

I&C systems rely heavily on logic strings to determine whether various automatic actions need to occur in response to one or more abnormal inputs. Logic system functional tests are used to assess whether a logic string responds appropriately to a simulated or actual input to ensure that no portion of the logic string is faulted. Modern digital platforms include self-diagnostic features which can detect system failures in real time to ensure that I&C systems remain capable of performing their specified functions. Faults are annunciated so that plant O&M personnel can take the appropriate action. This eliminates the need to perform time-based surveillances of the same equipment and eliminates the potential that a hidden failure exists until the next instance of a time-based surveillance.

Currently, logic system function tests are performed quarterly, whereas a digital system is constantly monitoring the logic functionality, eliminating the need for time-based manual testing. The benefits analysis eliminated 100% of the workload associated with these tests.

**Functional Tests**

Functional tests verify that all elements of a control loop respond appropriately to simulated or actual input to the loop. Modern digital platforms include self-diagnostic features which are capable of detecting system failures in real time to ensure that I&C systems remain capable of performing their specified functions. Faults are annunciated so that plant O&M personnel can take the appropriate action. This eliminates the need to perform time-based surveillances of the same equipment and it eliminates the potential that a hidden failure exists until the next instance of a time-based surveillance.

Although functional tests were not eliminated entirely in the benefits analysis, a significant reduction of field maintenance and operations labor is expected as the need to install temporary modifications to perform the test is eliminated.

**Channel Checks**

Channel checks are performed to ensure that redundant analog instrument channels are reading values that are within an acceptable range of one another. The broader I&C modernization efforts at the Station make use of safety-related and non-safety related digital platforms and other digital networks. The data obtained by the safety-related platform will be transferred unidirectionally to the non-safety related platform. Software in the non-safety related or other appropriate digital platforms compares the data from redundant transmitters, checking that all readings are within an acceptable range defined for each transmitter. This function is carried out automatically, eliminating the need for manual channel checks and the surveillance requirements that drive their performance.

**Calibration Tests**

All calibrations for legacy analog trip units are eliminated by the replacement digital systems through the nature of the new system design and/or the application of self-diagnostic features of the new system.

Analog sensing instrument performance is typically maintained by periodic, time-based calibration. Calibration is still required for most sensing instruments due to their tendency to drift. The use of Online Monitoring (OLM) techniques has the potential to eliminate the need for time-based calibration activities for the analog sensing units through the implementation of condition-based maintenance. Condition-based maintenance would only be performed when monitored conditions are determined to be out of prescribed bounds for that sensing instrument. In the future, OLM is expected to be implemented by the new digital platform transmitting sensor data to application software in a non-safety system to determine whether the equipment has encountered an anomaly or fault that requires recalibration. This, in turn, would allow the extension of existing surveillance test frequencies for calibration.

The benefits analysis did not credit extension of sensing instrument calibration since this type of OLM has not been adequately demonstrated in a nuclear environment. The PPS platform will have the capability of transmitting data to non-safety digital systems for the purpose of enabling future OLM capabilities to reduce sensor calibration activities as these techniques mature.

**Response Time Tests**

Response time tests are used to ensure that a control loop responds in an appropriate amount of time to a simulated or actual input signal. Digital processing equipment does not suffer the effects of drift that must be accounted for with analog I&C equipment. Therefore, following initial factory acceptance testing whereby the control loop timing is verified, it is not expected that further response time testing will be required. Further, degradation of internal electronics which could impact system response time will be detected using self-diagnostic capabilities inherent with the digital platform. Response time tests for equipment external to the PPS is still required.

Response time tests were not completely eliminated in the benefits analysis. Credit was taken for the expected workload reductions associated with manipulating analog devices during the test.

**Shift Surveillances**

The benefits analysis also takes full credit for eliminating shift surveillances (i.e., collection of field data, verification, and analysis) by Operations personnel. All such activities are eliminated by digitizing the field data and passing it to the non-safety related platform for recording and analysis.

#### 2.3.1.2 Preventive and Corrective Maintenance Workload Reductions

**I/O Cards**

Existing I/O equipment is replaced in its entirety by modernized I/O equipment that is less susceptible to failure. This reduction in failure risk is expected to convey to a similar reduction in Preventive Maintenance (PM) scope for this type of equipment.

**Trip Units**

Analog trip units will be eliminated in their entirety to support implementation of the modernized digital platform. The existing functions performed by the analog trip units will be performed through the use of modernized I/O equipment and application software. Application software does not require the performance of PM. Additionally, modernized I/O equipment will require a reduced scope of PM compared to existing analog trip units.

**Relays**

Legacy relays (e.g., Agastat) used in existing I&C architectures will be eliminated and replaced with application software running on modern digital platforms. Any switching functions used in the modernized platform will make use of solid-state electronics. Planned maintenance activities do not need to be performed on application software. Additionally, solid-state electronics have fewer potential failure modes when compared to existing electromechanical relays currently in use at the Station, thus necessitating fewer planned maintenance activities. Together, these design attributes have the effect of lowering the PM costs currently attributed to existing relays.

**Contacts and Coils**

Contacts and coils used in existing I&C architectures will be eliminated and replaced with solid-state electronics and application software. Solid-state electronics have no moving parts. This lowers the number of failure modes when compared to electromechanical devices, permitting a reduced scope of PM compared to the current scope associated with electromechanical equipment. Contactors that are expected to remain as part of the new system (e.g., RPS scram contactors) will be replaced by modernized equipment with inherently increased reliability. Application software is expected to replace some logic-based functions which were previously performed using relay contacts. Application software does not require the performance of PM.

**Power Supply**

Implementation of a modernized platform will include the use of redundant power distribution units. Use of modernized equipment, combined with a robust lifecycle support strategy, will reduce the obsolescence and overall material costs associated with this equipment.

**Field Instrumentation**

Labor associated with planned and unplanned maintenance of field instrumentation will be reduced in two ways as part of digital platform implementation: (1) elimination (e.g., abandon in place) of redundant transmitters for sensed variables such as reactor water level and reactor pressure and (2) implementation of OLM by leveraging non-safety related application software. The digital platform enables the use of a smaller set of redundant sensing instruments to perform multiple functions. This enables the elimination of separate, redundant sensing elements that separately support RPS, N4S, and ECCS and inherently reduces the total number of PM activities required for sensing instrumentation. In the future, OLM will permit the use of condition-based maintenance whereby calibration is only performed when necessary, as opposed to time-based maintenance strategies. Support of future OLM will be implemented as part of the new non-safety digital platform.  Future non-safety related algorithms will be developed to estimate whether the sensing equipment has encountered an anomaly or fault that requires recalibration.

#### 2.3.1.3 Incident Reports and Corrective Actions Workload Reductions

Existing safety system I&C architectures rely on electromechanical devices and vintage digital components to monitor and react to signals received from field instrumentation. These devices are inherently less reliable than modern digital platforms. In legacy systems, these shortcomings are overcome, in part, by designing systems with redundant channels and voting logic schemes. Combined, these characteristics of legacy I&C architectures yield several consequential failure modes. Failures associated with this type of equipment require reporting and event investigation in accordance with the plant's CAP. Failure modes and rates associated with modern digital platforms and associated equipment are expected to be much lower. The benefits analysis eliminated effort expended on reporting and investigating events caused by failures of legacy safety system I&C components.

### 2.3.2 Materials Benefits

#### 2.3.2.1 Annual Material Expenditure Reductions

For reasons already outlined in Section 2.3.1.2, it is expected the Station will experience lower material costs proportionate with reductions in preventive and corrective maintenance workload. These activities generally require some level of parts (materials) replacement which will no longer be required for eliminated components. It is expected that a ~75% reduction of RPS, N4S, and ECCS input sensors and system hardware components will be achieved through implementation of the digital PPS.

#### 2.3.2.2 Carrying Cost of Inventory Reductions

With a simplified architecture and solid-state components, the Owner will no longer be required to maintain a significant quantity of spare parts and components in inventory to respond to planned and unplanned maintenance activities. The elimination of inventory will provide the opportunity for the Owner to reduce inventory carrying cost.

#### 2.3.2.3 Avoided Cost Attributable to Obsolescence

In addition, prices for replacement of specialized components of the current legacy safety systems are increasing. As many of these components are obsolete, they have experienced a deterioration in reliability while, at the same time, prices for refurbished components have increased at an accelerating rate over the past 10 years (refer to Appendix C—A Case Study in Component Obsolescence). Replacement with a modernized digital system coupled with obsolescence management as part of a lifecycle support strategy will address the exponential growth of legacy system component costs.

## 3. Business Case Analysis Methodology

The BCA methodology was drafted to systematically evaluate and forecast expected lifecycle costs for the safety-related I&C systems targeted for modernization. This is depicted in Figure 5 below.

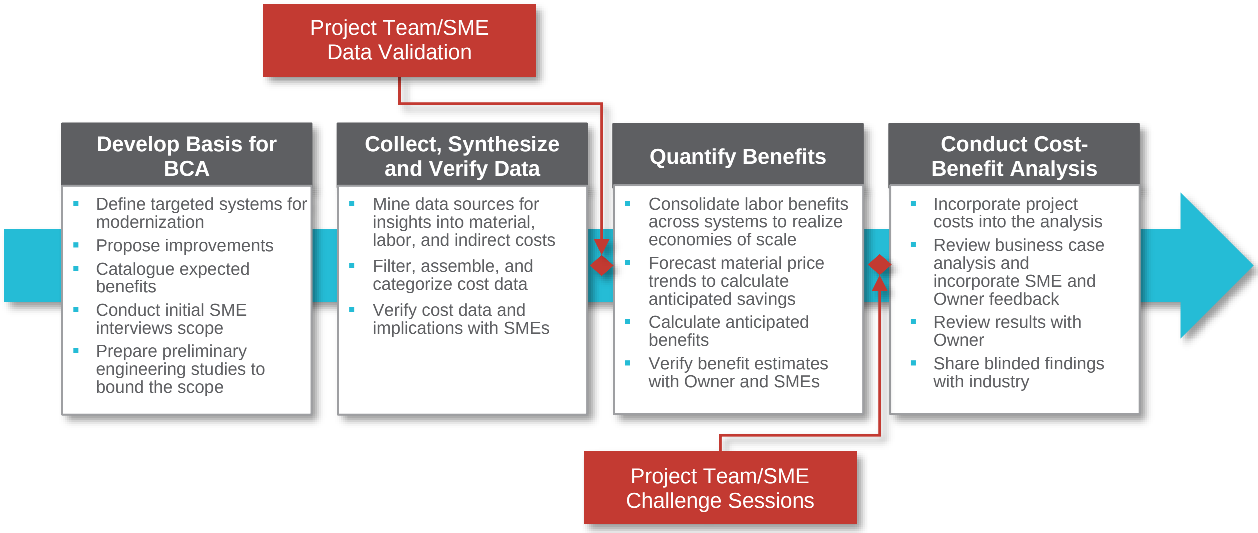


Figure 5: Business Case Analysis methodology.

The methodology provided an approach for the Project Team to build the business case for the modernization by:

1. *Developing a basis for and bounding the scope of the BCA*
   - Definitively bound the scope of current I&C systems envisioned for modernization
   - Propose system improvements and describe key features of modernization that may offer potential for financial benefit
   - Conduct initial interviews with SMEs to hypothesize potential reductions in labor and material costs enabled by identified system improvements/key features
   - Catalog expected benefits of the proposed digital modernization
   - Prepare preliminary engineering studies and deliverables to support data collection activities

2. *Collecting and synthesizing historical data and determining costs associated with current safety-related I&C systems*
   - Mine data sources that bound cost contributors related to the systems to be upgraded (Contributors include historical material costs and trends, direct labor costs to maintain and support the systems, including surveillances, and indirect costs such as CAP activities)
   - Filter, assemble, and categorize cost data into workbooks
   - Apply enablers of quantifiable Project benefits to the cost data to support validation
   - Present and validate cost data with SMEs to further identify existing system costs

3. *Quantifying benefits associated with proposed modernization of safety-related I&C systems*
   In collaboration with engineers familiar with the attributes of the digital equipment to be used in the upgrade and its envisioned application; cost savings categories and expected savings in those categories are then identified and applied using the analysis tools developed for this purpose. This effort includes:
   - Consolidating enabled workload reductions across existing systems to exploit features and economies of scale of the new digital systems and quantify harvestable labor benefits
   - Analyzing existing system historical data of purchased materials and expenditures to forecast avoided lifecycle costs enabled by the new digital systems
   - Presenting and challenging benefit estimates with SMEs and management representatives to refine those estimates based on expert judgement and achieving cross-functional consensus

The result is a Present Value (PV) of benefits and savings enabled by the upgrade. This includes both direct cost savings (e.g., surveillance labor costs) as well as cost avoidance items (e.g., inventory carrying costs)

4. *Conducting financial cost-benefit analysis of BCA results*
   - Comparing costs to implement and operate the proposed modernized I&C systems to avoided costs (i.e., benefits) of maintaining current system
   - Present Project metrics of Net Present Value (NPV), Internal Rate of Return (IRR) and payback period to Owner's leadership.

The BCA results, which are limited to the development of a detailed cost-benefit analysis, are considered proprietary to the Owner and are provided in a limited distribution version of this research product. For this public version, financial data have been altered to protect the Owner's proprietary information. As presented, financial data included herein is intended to be illustrative and representative in scale of benefits and is not intended to provide material data utilized in the Owner's financial analysis. The ultimate purpose of this public, non-proprietary version is to communicate the process and related business case tool to enable similar BCAs for digital upgrades throughout the industry. It is expected that this methodology can be abstracted and used for nearly any system upgrade.

This research also includes a presentation (developed in Microsoft PowerPoint) of the benefits of the envisioned digital I&C safety system upgrade to further enable the generation of a compelling case for upgrade to both plant and utility management. This is provided in Appendix D.

# 4. Development of Basis for Business Case Analysis

In order to effectively prepare a BCA, the scope of the modernization must first be bound to a basis. While initiating the Project, initial discussions were focused on reviewing and applying the Advanced Concept of Operations described in Section 1.3 and determining how it could best be applied at the Station as an integrated digital replacement for current safety-related systems. These initial discussions resulted in a preliminary list of four targeted safety-related systems that baselined the Project Team in continued discussions of the benefits that could be achieved with such a solution. These initial discussions were progressively elaborated during the development of the Project in order to bound the scope of the modernization, define key features that would enable benefits, then catalog those potential benefits.

## 4.1 Define Target Safety-Related Systems

Systems targeted for modernization need to be defined at appropriate levels of detail for the Project benefits to be estimated. Defining the extent of the modernization defines the limits of the BCA and serves to direct data acquisition and mining efforts. A full description of the existing safety-related systems proposed for modernization at the Station is provided in Section 2.1 above.

## 4.2 Define Architecture and Key Features of Proposed Modernization

Project benefits are primarily based on understanding the associated avoided operational and maintenance costs. The architecture and key features of the proposed modernization need to be defined to the extent that the detailed engineering studies can be conducted to identify the equipment and components that are functionally replaced or removed by implementation of the proposed modernized systems. A full description of the architecture and key features of the proposed digital modernization is provided in Section 2.2 above.

## 4.3 Catalog Expected Benefits

A catalog of expected benefits is necessary to plan and direct BCA activities. The expected benefits serve as a hypothesis for the Project Team to verify through data acquisition and analysis. Understanding the expected benefits guides the design of a construct for the analysis which then informs the data that needs to be collected. A full description of expected benefits of the proposed digital modernization is provided in Section 2.3 above.

## 4.4 Conduct Initial Interviews with SMEs

A series of interviews were conducted with Station SMEs where the SMEs were presented the Project scope and an overview of the expected benefits. These interviews served multiple purposes:

1. Review the Project scope and objectives with SMEs and inform them on their supporting role in development of the BCA.
2. Review expected benefits and determine if additional categories should be investigated.
3. Exchange ideas on how labor and material benefits are evaluated and highlight the sources of data.
4. Determine if additional SMEs should be interviewed or included in the review and validation of data.

## 4.5 Prepare Preliminary Engineering Studies

Once design concept work had begun for the Project, it became immediately apparent that a much more detailed scope boundary needed to be established to enable development of a complete design concept and the BCA.

The referenced BWR plant design contains several systems which interface directly or indirectly with the RPS, N4S, ECCS and/or ATWS Mitigation System. These interfaces are typically facilitated by electronic equipment that control and monitor operation of the interfacing system. The equipment associated with these interfacing systems is typically classified as part of the interfacing system and not with the RPS, N4S, ECCS and/or ATWS Mitigation System. For example, a relay that senses main steam line pressure interfaces with the N4S but is classified as part of the Main Steam system. This type of relay would be eliminated as part of the PPS implementation. Limiting the benefits analysis equipment scope to only the RPS, N4S, ECCS and ATWS Mitigation System would inadvertently exclude this type of equipment from the benefits analysis. Furthermore, additional electronic devices in the RPS, N4S, ECCS, and the ATWS Mitigation System cabinets are present that are not assigned to these systems; however, these devices use the same or similar technology or present insufficient data in the MCR. These also needed to be included in the Project scope. As a result, the Project scope expanded from the electronic devices directly associated with RPS, N4S, ECCS, and the ATWS Mitigation System in plant documentation to also include electronic devices from a total of 20 discrete plant systems shown in **Error! Reference source not found.** below. This greatly increased the set of lifecycle cost information t hat needed to be collected for the BCA.

Table 1: In-scope system list.

| Plant System Code | Primary System | Subsystem |
|---|---|---|
| 001 | N4S | Main Steam |
| 025 | N4S | Temp Monitoring |
| 026 | N4S | Radiation and Meteorological Monitoring System |
| 036 | ATWS Mitigation System | ATWS Mitigation System |
| 041 | ECCS | Main Steam/ADS |
| 042 | Common | Nuclear Boiler Instrumentation |
| 044 | N4S | Reactor Water Cleanup |
| 046 | RPS | Control Rod Drive |
| 048 | ATWS Mitigation System | Standby Liquid Control |
| 049 | ECCS | RCIC |
| 050 | ECCS | ADS |
| 051 | ECCS | RHR |
| 052 | ECCS | Core Spray |
| 055 | ECCS | HPCI |
| 056 | ECCS | HPCI |
| 059 | N4S | PCIG & TIP Power Supply |
| 071 | RPS | RPS |
| 072 | N4S | N4S |
| 076 | N4S | HVAC |
| 092 | ECCS | Emergency Diesel Generators |

In order to efficiently process the vast amounts of historical plant data associated with 20 plant systems, the Project Team conducted engineering studies of the plant design to ultimately develop the following lists to support data collection, segregation, and synthesis:

1. In-Scope System List: As explained above, the initial In-Scope System List expanded from four to 20 of the approximately 120 plant systems on record in the Work Management System (WMS). The In-Scope System List was used to direct and limit data-mining activities to the in-scope systems identified in **Error! Reference source not found.** above. How this list was used to c ollect and categorize data sourced from the WMS is further described in Section 5 below.

2. In-Scope Equipment List: The product of this effort was ultimately a list of all equipment that would be replaced or eliminated by the proposed modernization effort. How this list was used to mine, filter, and synthesize data sourced from the Station's WMS is further described in Section 5 below.

3. Planned Maintenance Item (PMI) List: A PMI List is a schedule of active, inactive, and retired planned maintenance items for both units at the Owner site. It was produced by the Station's System Engineering group. PMIs are planned recurring maintenance activities that are executed on a defined schedule. Each of these recurring activities is assigned a unique ID number (i.e., PMID), a prescribed frequency, and an indication of whether the activity must be completed during an outage or while the plant is online. How this list was used to mine, filter, and synthesize data sourced from the Station's WMS is further described in Section 5 below.

4. Surveillance and Test List: A list of all required Surveillance and Tests (ST) was provided that cross-referenced Station technical specifications requirements for the in-scope safety-related

systems, related ST procedures and PMID numbers. How this list was used to mine, filter, and synthesize data sourced from the Station's WMS is further described in Section 5 below.

# 5. Collection, Synthesis, Verification and Validation of Data Related to Target Safety-Related I&C Systems

To perform a BCA for any system upgrade, the costs associated with continued operation and maintenance of the current systems through the remaining operational lifetime of the unit must be established. To accomplish this, collection, synthesis, and verification of historical cost data was performed to allow identification of trends and forecast of costs for the systems. The basis of the system upgrade as presented in Section 2.1 represents a good starting point for general understanding of the overall upgrade. The subsections below provide an overview of the methods employed to develop and present labor workload associated with existing safety-related systems.

To establish the full breadth of costs to maintain the current RPS, N4S, ECCS, and ATWS Mitigation System and associated subsystem electronic equipment, data mining labor categories were identified along with where that data was captured at the research subject units. Labor data was then gathered and synthesized to create worksheets within a Microsoft Excel workbook that served as a foundation for the BCA. Material data was similarly gathered and synthesized with the results also captured within the same Microsoft Excel workbook. Verification and validation of labor and material data by SMEs was performed in areas where savings were expected. Activities associated with this effort are described below. Additional information regarding the systematic approach, as well as sample job aids used to perform the activities described above are available in Appendix A—Systematic Presentation of Business Case Analysis Process, and Appendix B—Business Case Analysis Workbook.

## 5.1 Collection, Synthesis, Verification, and Validation of Operations and Maintenance Labor Workload

### 5.1.1 Data Mining of Raw Labor Data Sourced from Station Work Management System

Direct O&M labor workload tied to existing in-scope safety-related systems and associated in-scope equipment identified by engineering in the lists described in Section 4.5 were largely collected from examination of historical records of Work Orders (WOs) sourced from the Station's WMS. Custom WMS reports were developed for each in-scope system with the support of the Station's IT department. Each report provided a set of all recorded WO tasks for a particular system over the history of the Station. Each task identified the resources required and the estimated hours to complete.

The resulting WMS report data files were large and cumbersome, many containing hundreds of thousands of discrete records dating back more than 30 years. To mitigate this, each of the WMS data files was filtered to provide data for the most recent 5 years and segregated into categories of activities. These results were consolidated to produce the three data files described below:

1. Surveillance and Test (ST) Data File – ST WOs are planned activities performed by station resources primarily to satisfy regulatory requirements (e.g., Technical Specifications). The raw data files sourced from the WMS for each system were mined for WOs that reference active PMIs on the PMI List and also included on the ST List. The resulting data from each of the 20 subsystems were then consolidated into a single data file that provided a historical record of WO tasks and resources expended to complete in-scope ST WOs over the past 5 years.
2. Preventive Maintenance (PM) Data File – PM WOs are planned maintenance activities performed by Station resources triggered by PMIs as part of the Station's equipment reliability program. The raw data files sourced from the WMS for each system were mined for PM WOs that reference

PMIs on the PMI List described in Section 4.5 above as "active" (i.e., inactive or retired PMIs were excluded). The mined data were then filtered to remove PMIs also included on the ST List so as not to replicate these activities in both lists. The remaining data from each of the 20 subsystems were then consolidated into a single data file and filtered further to include only WO tasks that were tied to equipment included in the In-Scope Equipment List, described in Section 4.5 above. The resulting data file provided a historical record of WO tasks, as well as historical resources and expended effort to complete in-scope PM WOs over the past 5 years.

3. Corrective Maintenance (CM) Data File – CM WOs are unplanned maintenance activities required to be performed to support continuity of operations and in response to Station observations, condition reports and/or incident reports. The raw data files sourced from the WMS for each system were mined for WOs that were tagged as CM WOs in the WMS System. The data were then filtered to omit data not included on the In-Scope Equipment List described in Section 4.5 above. The remaining data from each of the 20 subsystems were then consolidated into a single data file that provided a historical record of CM WO tasks performed to execute CM WOs over the past 5 years.

### 5.1.2 Synthesis and Presentation of Surveillance and Test Workload

To develop an estimate of expected ST workload reductions attributable to existing systems impacted by the proposed modernization, an MS Excel worksheet was created in the BCA Workbook [Appendix B] to synthesize information provided in the PMI List. For each required, recurring PMI identified in the PMI List (described in Section 4.5), the Project Team modeled tasks and resources required and established the expected workload utilizing the historical labor data included in the ST Data File. Additional workload to support ST WOs, such as craft supervision, planning, scheduling, work management, and system engineering support not included in the WMS WO data, were identified as part of the data verification and validation process described in Section 5.1.5 below, and added to the ST Excel worksheet.

### 5.1.3 Synthesis and Presentation of Preventive Maintenance Workload

To develop an estimate of expected PM workload reductions attributable to existing systems impacted by the proposed modernization, an MS Excel worksheet was created in the BCA Workbook [Appendix B] to synthesize information provided in the PMI List. For each required, recurring PMI identified in the PMI List described in Section 4.5, the Project Team modeled tasks and resources required, and established the expected workload utilizing the historical labor data included in the PM Data File. Additional workload to support PM WOs, such as craft supervision, planning, scheduling, work management, and system engineering support that are not included in the WMS WO data were identified as part of the data verification and validation process described in Section 5.1.5 below, and added to the PM Excel worksheet.

### 5.1.4 Synthesis and Presentation of Corrective Maintenance Workload

To develop an estimate of unplanned CM workload reductions attributable to existing systems impacted by the proposed modernization, the CM Data File was used as a source. Unlike planned maintenance WOs (i.e., ST and PM WOs), unplanned CM WOs do not lend themselves to forecasting at the task level. Instead, the 5-year trend of annual workload for each resource type, sometimes described as a "run-rate," was used as the basis to trend workload into future years. Additional workload to support field labor activities, such as craft supervision, planning, scheduling, and system engineering not included in the WMS WO data were estimated by factoring the number of tasks and CM WOs associated with in-scope equipment. The results of this activity were also captured in a CM workload worksheet created in the BCA Workbook [Appendix B]. These factored estimates were reviewed by SMEs as part of the verification and validation sessions described in Section 5.1.5 below.

### 5.1.5 Verification and Validation of Operations and Maintenance Workload

A series of workshops were conducted with SMEs to verify the estimated workload reductions synthesized from the engineering studies lists and mined data. These workshops also engaged the SMEs to validate how the key features and enablers of quantifiable Project benefits (Section 2.2.2) and the description of expected benefits (Section 2.3) were applied to the data by Engineering personnel to identify specific areas of potential workload reductions. SMEs included representatives from I&C Maintenance Craft, I&C Maintenance Supervision, Maintenance Preparation (Scheduling and Planning), Work Management, Outage Management, Operations, and System Engineering. Where needed, follow-up interviews were conducted with additional SMEs identified to confirm open items generated in the workshops.

The objectives of these sessions were to:

1. Provide SMEs with an overview on how the data was collected by Engineering and Business Analysts and compiled in the BCA Workbook to confirm the approach is reasonable
2. Validate the detailed data presented is reflective of their experience as SMEs and adjust or correct where warranted
3. Provide an opportunity to make necessary adjustments to the data based on SME experience (i.e., there might be wide discrepancies in the resources and time required on various WOs that need to be reconciled)
4. Identify additional support tasks not identified on the WOs (i.e., WOs will identify field labor to perform tasks as part of a WO, but they generally do not identify time spent scheduling, coordinating, and supervising the work, which are tasks added in manually by the Project Team based on SME input)
5. Verify that the workload described in the data can be eliminated as identified by Engineering and captured in the BCA Excel Workbook based on the scope and description of benefits of the proposed modernization of safety-related systems; where the workload is only partially eliminated, SMEs were asked to assign a percentage value for the reduction
6. Verify that the consolidated results indicating total workload reduction are within the bounds of available resources assigned to the Station.

## 5.2 Collection, Synthesis, Verification, and Validation of Incident Reporting and Event Management Workload

While the Station's WMS System provides a very detailed picture of field labor expended to operate and maintain the targeted systems, data was also examined to quantify workload associated with incident reporting and event management. This represents the work that occurs to identify, document, and analyze recorded incidents and events at the Station. The Project Team turned to the Station's CAP management System as a source of data to estimate the workload as described in subsequent sections below. Additional information regarding the systematic approach utilized, as well as sample job aids used to perform the activities described above, are available in Appendix A—Systematic Presentation of Business Case Analysis Process and Appendix B—Business Case Analysis Workbook, each appended to this research product.

### 5.2.1 Data Mining Incident Report Data from the Station Corrective Action Program Management System

For each in-scope system, a data set of incident reports sourced from the Station's CAP management system was created. Incidents are classified in the CAP system in three types and are coarsely defined as:

- Class A – Major incidents that required a root cause analysis
- Class B – Incidents that required an apparent cause evaluation or similar type of study
- Class D – Minor incidents that required a work group evaluation or no formal evaluation was required.

Class C is no longer used. The incident reports were then individually examined as part of a workshop with SMEs to determine if the incident was caused by a failure of in-scope equipment (i.e., equipment subject to replacement or elimination as a result of the proposed modernization) or another cause not identified as a quantitative benefit in Section 2.2.2 (e.g., human factors, which is identified as a qualitative benefit in Section 2.2.3). Items not identified as providing a quantitative benefit were removed from the data set. The resulting data set provided a count of incidents, categorized by class, over a period of 5 years.

### 5.2.2 Synthesis and Presentation of Incident Reporting and Event Management Workload

A review of Station procedures related to incident reporting and event management was conducted. As the workshop examined the series of steps and reviews necessary to respond to and manage incidents and events, workload was estimated for each step. Since responses can vary significantly between events, the workshop asked the participants to estimate typical hours required to perform activities to close each class of incident described in Section 5.2.1 above. Synthesizing these estimates with the average incident rate for each class of incident produced an estimate of total workload for this benefit category. This information was also captured in the BCA Excel Workbook for each scoped system.

### 5.2.3 Verification and Validation of Incident Reporting and Event Management Workload

Incident reporting and CAP data were verified and validated as part of a workshop with SMEs. SMEs included representatives from I&C Maintenance Craft, I&C Maintenance Supervision, Maintenance Preparation (Scheduling and Planning), Work Management, Outage Management, Operations, and System Engineering. The objectives of the validation included:

1. Determining if the incident report and resulting responses were caused by a failure of in-scope equipment, or if they were due to another cause not identified as a quantitative benefit in Section 2.2.2 (e.g., human factors, which is identified as a qualitative benefit in Section 2.2.3). Those incidents determined not to provide quantitative benefit were removed from the data set.
2. Reviewing the estimated workload reductions for each class of incident as identified by Engineering, and validating if the estimates presented in the BCA Workbook are reflective of their experience as SMEs, then adjusting or correcting where warranted.

## 5.3 Other Labor Categories Examined

### 5.3.1 Engineering

The Project Team conducted interviews with System Engineers to estimate the level of support that would no longer be necessary with a modern digital system. System Engineers currently spend a significant portion of their time troubleshooting system faults and failed system components and supporting procurement in sourcing and refurbishing components that are approaching obsolescence (primarily in support of the ATWS Mitigation System). It was postulated that improved reliability of modern solid-state components would eliminate much of these efforts. The Project Team applied an estimate for System Engineering workload reduction as approximately 8–10% of a System Engineer's time and included this in the aggregated workload reductions.

### 5.3.2 Supply Chain and Warehousing

The Project Team conducted interviews with Supply Chain SMEs to determine if quantifiable benefits could be credited to the Project. Through discovery, it was determined that procurement and warehousing functions are corporate support functions provided to the Station, and are not part of the Station's budget. More specifically, it was not likely that the implementation of the modernization would change the current level of support provided to the plant and, therefore, the Project Team was unable to credit any quantifiable benefit to this function.

### 5.3.3 Training

Through interviews with Operations, Maintenance, and, Training program managers, and an examination of training content and delivery, it was determined that no appreciable reductions would be realized in either operations or maintenance training regimens. The assessment of the Operator Training Program indicated that, while some training materials would be modified, the overall content and frequency of training would not be reduced. Training for the legacy systems would be replaced with training on the new systems. The assessment of the Maintenance Training Program indicated that the program is based on development of craft qualifications, and that the proposed scope would not impact qualifications required to perform day-to-day activities across the plant.

### 5.3.4 Contract Labor

The Project Team examined whether any of the in-scope work related to the targeted safety-related systems were performed by contract labor. The Station did not identify any standing contract arrangements to support maintenance of the targeted safety-related systems.

## 5.4 Collection, Synthesis, Verification, and Validation of Material Expenditures and Value of Inventory

### 5.4.1 Data Mining of Material Purchase and Inventory Data from the Station WMS and Procurement System

To develop an estimate of material expenditures related to the target safety-related systems, the Project Team had to overcome the challenge of working with two data sources, each with its own limitations:

1. <u>Station WMS:</u> The Station's WMS provided information relating to components and materials planned with WOs but did not provide a record if the component or material was actually expended with the work. For example, a WO may indicate that a component (e.g., an I/O card) was required on hand to execute a planned maintenance task, but did not indicate whether the component was installed or was returned to stores when the task was complete. Additionally, estimated component and material costs provided in the WMS were often not listed or were unreliable.

2. Station Procurement System: The Station Procurement System provided historical information of purchases made for materials and components, but did not link those purchases to a WO or an equipment item number.

The two data sources above are linked by a common data key of Catalog Identification Number (CATID) and this key was utilized to produce a rational estimate of material expenditures and valuation of inventory as described below.

#### 5.4.1.1 Data Mining of Material Data from the Station Work Management System

In a similar fashion to acquiring labor data from the WMS, custom reports were created with the support of the Station's IT department for each in-scope system. Each system report provided CATIDs of components called out in historical WOs. The data were then filtered against the in-scope equipment list and pivoted to create a table of CATIDs associated with in-scope equipment that could be rolled up to the target safety-related systems[2].

This list was manually scrubbed by the Project Team to eliminate expendable materials (e.g., cable, tubing, grease) and common materials that could be utilized anywhere in the Station (e.g., fuses, panel fans, light bulbs). The resulting list was utilized to mine purchasing data from the Station procurement system.

#### 5.4.1.2 Data Mining of Material Data from the Station Procurement System

For each catalog item identified from mining of WMS data, the Project Team utilized historical purchasing data in the Station procurement system to document:

1. Historical purchases (quantity, unit price, and purchase year) over the past 10 years; data was used to establish growth rates of component unit prices and material expenditures
2. The most recent purchase price paid for the catalog item
3. The average expenditure over the most recent 5 years
4. The current quantity in inventory

### 5.4.2 Synthesizing and Presentation of Material Expenditures and Value of Inventory

The results of mining both the WMS and Procurement System were synthesized and presented in an MS Excel worksheet for each of the primary targeted safety-related systems in the BCA Workbook. The historical purchase data was used to estimate a weighted average Compound Annual Growth Rate (CAGR) for the price of system components[3]. This value was used to adjust historical purchase prices to current values and determine the value of inventory for each component. The resulting table provides the estimated annual expenditure and value of inventory in current dollars for each component. Additional information regarding the systematic approach utilized as well as sample job aids used to perform the activities described above are available in Appendix A—Systematic Presentation of Business Case Analysis Process, and Appendix B—Business Case Analysis Workbook appended to this research product.

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[2] In cases where a CATID was common to multiple target systems, the Project Team estimated an allocation of each of the target systems sharing the component in proportion with the number of instances that component was called out in the WMS.

[3] Not all CATIDs had enough instances of purchases to determine a CAGR. A sample set of the costliest components in terms of total expenditure (quantity x price) were used to determine a weighted average CAGR of component unit costs and applied across all components in a system. As a guide, the Project Team applied the "80–20" rule to identify enough sample components to represent a majority of material expenditures.

### 5.4.3 Verification and Validation of Material Expenditures and Carrying Costs of Inventory

The Project Team verified data related to material purchases in inventory levels as part of a data verification and validation workshop with SMEs from Procurement, Warehousing, Maintenance, and System Engineering. The objectives of the workshop were to:

1. Review the methods used by Engineering and Business Analysts to mine, filter, and synthesize data in the BCA Excel Workbook and confirm that the approach is rational.
2. Validate the purchase data, unit costs, and inventory levels presented are reflective of their experience as SMEs and adjust or correct where warranted.
3. Verify that the consolidated results presented are aligned with their overall expectations as SMEs and adjust or correct where warranted.

# 6. Quantifying Benefits of the Proposed Digital Safety-Related I&C Systems

## 6.1 Quantification of Labor Benefits

Once labor data collection activities were completed and workload reductions attributable to in-scope equipment were validated, a summary of this data is assembled onto a single table in order to support quantification of labor benefit. The summary data is provided by resource type and segregated into the following categories and subcategories.

- Online Labor
    - Target System (e.g., RPS, ECCS, Common)
        - Surveillance and Test
        - Preventive Maintenance
        - Corrective Maintenance
        - Other Support (e.g., CAP, System Engineering, Training)
- Outage Labor
    - Target System
        - Surveillance and Test
        - Preventive Maintenance
        - Corrective Maintenance
        - Other Support.

Presenting the workload reductions in this way in the BCA Excel Workbook allowed the Project Team to demonstrate how these reductions can be actualized as budget reductions at the Station. Benefits that can be translated to staffing adjustments are regarded as harvestable labor benefits. For the purposes of estimating staffing adjustments, the Project Team considered online workload reductions as harvestable. Outage workload adjustments, which are supported by external labor sourced from contracts or from other Stations, were not considered as harvestable by the Station, but rather redeemable as reductions of temporary support, contracted or otherwise, transferred from other Stations.

### 6.1.1 Treatment of Harvestable Online Workload Reductions

Harvestability is defined as the actual reduction in required workload in units of Full Time Equivalents (FTEs) notwithstanding regulatory staffing requirements. More specifically, estimated workload reductions must be at least equal or greater than one FTE in resource-hours for a particular resource function to be counted as harvestable. To determine harvestability, the Project Team summed up the total online workload reductions by resource types and determined if the workload reduction was great enough to affect an organization in terms of the number of FTEs. The following examples illustrate how the concept of harvestability can be applied.

**Example 1.**

A benefits analysis has been completed on a station initiative to outsource operation of a water dosing system to an external contractor. The Project indicates that the station may expect an annual reduction of 250 hours of mechanical maintenance labor and 1,050 hours in chemistry labor. The FTE equivalent is 1,400 hours for a mechanical craft person and 1,600 hours for a chemistry technician. This workload reduction is therefore not harvestable as the workload reductions do not meet the threshold of one FTE for either resource type.

In some cases, like resources from different work groups can be combined to achieve harvestability.

**Example 2.**

A station is considering implementing a new computer-based WMS featuring paperless WOs. A benefits analysis has been completed that indicates workload related to clerical support in various work groups will be reduced as follows:

- *Mechanical Maintenance – 600 hours*
- *Electrical Maintenance – 1,350 hours*
- *Instrument Maintenance – 1,550 hours*
- *Maintenance Planning – 900 hours*

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*Total Clerical Workload Reduction – 4,400 hours*

The FTE equivalent of a clerical worker is 1,800 hours. Individually, the workload reductions listed above are not harvestable from any one work group. The Project Team then discussed the Project with department leads and determined that clerical resources could be shared between work groups in a way to support harvestability of two FTEs.

Regulatory staffing requirements can present an obstacle but can be overcome in certain situations:

**Example 3.**

A modernization of plant operations is being proposed for a station which is expected to reduce the workload of equipment operators by the equivalent of three FTEs. The station's Operations staffing currently is at the minimum allowed per shift under its current operating license. However, the workload reductions allow plant Operations to take on some field tasks currently performed by Chemistry. After analysis of the Chemistry workload that could be transferred to operations, the Project Team recognized that at least two FTEs could be harvested from Chemistry as a result of the modernization.

### 6.1.2 Treatment of Harvestable Outage Workload Reductions

Early in discovery, the Project Team recognized that a sizable portion of the workload reductions identified were executed during outages. Outages are periods where the unit is taken offline to perform maintenance activities that cannot otherwise be executed while the plant is in operation. Outages are typically 2 to 4 weeks in duration and must be supported with external labor to complete maintenance activities within this timeframe. For this reason, it would be imprudent to identify harvestable FTEs based on outage workload reductions. Rather, the Project Team credited outage workload reductions as outage contract labor savings and excluded outage workload reductions in the determination of harvestability of FTEs.

### 6.1.3 Treatment of Unharvestable Workload Reductions

The Project Team evaluated if unharvested workload reductions could be credited toward other budget reductions or qualitative performance improvements.

1. For resources that were determined to be eligible to receive compensation for overtime, unharvested workload reductions were credited as reduction in overtime and quantified as a benefit for the purposes of the BCA.
2. Any remaining unharvested labor benefits were recorded as available for other uses but were not quantified as monetary benefits for the purposes of the BCA. These benefits are identified and made available for management discretion, possibly to achieve other strategic objectives. Examples of strategic objectives where unharvested workload reductions might be utilized:
   - Reduction of backlog (i.e., maintenance, training)
   - Improved situational awareness (operations)
   - Participation in performance improvement efforts
   - Potential to combine savings with other initiatives.

## 6.2 Quantification of Materials Benefits

### 6.2.1 Estimating Annual Material Expenditure

Utilizing the materials data collected and synthesized for each CATID, the Project Team employed the 3-year average expenditure to estimate annual material expenditures for each targeted system (refer to Section 5.4.1). It was often the case that catalog items were common to multiple systems. In such cases, catalog item costs were allocated by the Project Team on a percentage basis to each target system. An additional allowance for miscellaneous, sundry, and expendable materials was factored into the estimate as a percentage of annual expenditure as a proxy for catalog items that had been scrubbed out of the data.

### 6.2.2 Establishing Escalation Rate of Total Material Expenditures

Understanding the escalation rate of material expenditures is necessary to trend expected benefits in future years. Anecdotal evidence produced during initial interviews made it apparent that material costs to support some of the targeted safety-related systems have been escalating at higher rates than what would be expected for a I&C system[4]. Rather than apply an industry standard material escalation rate to trend material costs in future years, an analysis was conducted to establish a definitive escalation rate for material expenditures for each of the targeted safety-related systems. Catalog items were sampled from each target system and analyzed to establish material expenditure growth rates over a 15-year period. The selection criteria for samples were based on the frequency of purchase and component total expenditure so that approximately 80% of total expenditures for each targeted system was represented in the sample set. The analysis of samples confirmed the hypothesis that overall material expenditures are increasing at CAGRs, higher than normally expected. The resulting CAGRs were used to Project expected material expenditures for each targeted system in future years and to demonstrate the Avoided Cost of Obsolescence (ACO) described in Section 6.2.3 below.

[4] For the purposes of estimating project costs and benefits, materials are typically estimated to escalate at a CAGR of 3–5% in industry. This factor generally accounts for inflation and increases in global commodity prices. It does not account for growing costs associated with declining reliability or shifts in market power due to limited availability of components. An in-depth analysis was conducted to quantify with greater precision the true escalation rates of materials to substantiate the hypothesis that component obsolescence is a factor driving year-on-year escalation of material expenditures.

### 6.2.3 Estimating Avoided Material Cost Attributable to Obsolescence

Based on early interviews with plant staff, the Project Team investigated reports of high escalation of component prices in recent years. An analysis of material costs for one system in-scope for replacement in this Project revealed that costs to maintain the system are escalating at a CAGR of more than 20%. This observed rate is higher than the expected rate of 3% to 5%, which is considered typical for the industry.

A comparative analysis of both labor and material trends for this sample system illustrated in Figure 6 below, demonstrates that although cost management efforts reduced the annual cost of labor to maintain the system over time, these gains have been offset by growth in cost of materials.

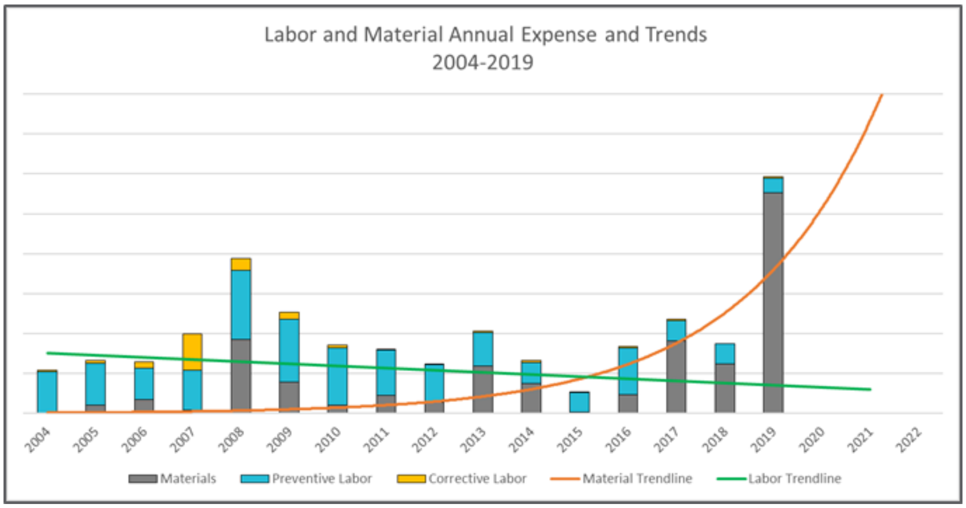


Figure 6: Sample system labor and material cost analysis.

A causal analysis produced the following contributing factors to this high growth rate:

- Annual material expenditure increases are driven by both escalating component unit prices and increasing failure rates of aging analog subcomponents
- Replacement components are harder to find, resulting in more supply chain and engineering time spent trying to procure the parts
- Limited supplier base has shifted market power to the shrinking number of vendors that still supply/service this equipment.

Given that obsolescence of components is the driving force behind rapidly increasing system costs, replacement of the obsolete components with a modern system would eliminate the current risks posed by this issue. A lifecycle management strategy of the newer system would further mitigate this risk from occurring in the future.

This research product defines the ACO as the difference between the PV of future material expenditures at observed escalation rates (e.g., 15–20% CAGR) and the PV of future material expenditures at expected escalation rates (e.g., 3–5% industry norm) and can be expressed by the formula provided below:

$$ACO = \sum_{n=First\ Year}^{Final\ Year} \frac{Material\ Expense_{n=0} \times \left[(1 + Rate_{Observed})^n - \left(1 + Rate_{Expected}\right)^n\right]}{(1 + Cost\ of\ Capital)^n}$$

Where:

$ACO = Present\ Value\ of\ Avoided\ Cost\ Attributable\ to\ Obsolescence$

$Material\ Expense_{n=0} = Current\ Average\ Annual\ Material\ Expenditure$

$Rate_{Observed} = Observed\ Historical\ Escalation\ Rate$

$Rate_{Expected} = Expected\ Escalation\ Rate\ (typically\ valued\ at\ three\ to\ five\ percent)$

$Cost\ of\ Capital = Cost\ of\ Capital\ (provided\ by\ Owner)$

$n = Nominal\ Year$

$First\ Year = Year\ in\ which\ cost\ is\ first\ avoided\ (i.e., after\ implementation)$

$Final\ Year = Year\ project\ lifecycle\ ends\ (defined\ by\ project\ team)$

### 6.2.4 One-Time Write-Off of Obsolete Inventory and Equipment

In cases where implementation of a project will strand obsolete parts and equipment, these items should be assessed to determine if they can be sold and/or written off the books. This analysis was conducted and credited as part of the Project cost estimate by the Owner and is outside the bounds of scope of this research product. However, an analyst conducting a subsequent BCA should consult with the Owner's finance team to determine proper treatment of these one-time benefits. In some cases, this benefit is written as part of the capital project as an offset of costs, and care should be taken not to double-count this on both sides of the BCA.

### 6.2.5 Estimating Current Value of Inventory

The current value of inventory was estimated utilizing historical purchase data of catalog items. The most recent purchasing unit cost for each CATID identified was mined from the Station procurement system. In many cases, the most recent purchase was several years in the past and needed to be adjusted to reflect current pricing; however, there were not enough instances of purchases to reliably establish rates of increases in cost over time. In a similar fashion to establish CAGR for total material expenditures above, a sample set of catalog items was selected from each target system and analyzed to establish unit pricing trends over a 15-year period. This in-depth analysis revealed that unit costs for specialized components were increasing at CAGRs higher than expected (see Appendix C—A Case Study in Obsolescence, for additional details). From this analysis, a weighted average of unit price CAGR was established for each targeted system. This CAGR was applied to historical unit prices to estimate the current value. The current value of inventory was then calculated by taking the sum-product of adjusted unit prices and quantity in inventory. In cases where components were shared by multiple systems, the value of inventory was allocated by the Project Team on a percentage basis to each target system.

### 6.2.6 Estimating Carrying Cost of Inventory

The carrying cost of inventory can be described as the burden of holding capital in inventory that may otherwise be invested elsewhere. The carrying cost of inventory was estimated as the sum of the components listed below:

- *Capital Carrying Cost:* Capital carrying cost represents the opportunity cost of maintaining assets in inventory that might otherwise be invested elsewhere. It is calculated as the *Value of Inventory* multiplied by the Owner's Cost of Capital (CoC).
- *Supply Chain and Warehousing Charges:* Supply chain and warehousing charges (if applicable) are the estimated costs for procurement and warehousing services borne by the Station.
- *Annual Depreciation:* Annual depreciation (if applicable) is the annual write down of the value of inventory in stores. Applicability of this depends on Owner's treatment of assets in inventory.
- *Property Taxes:* Property taxes (if applicable) are costs borne by the Owner based on value of inventory and regulations by the local taxing authority.
- *Insurance*: Insurance (if applicable) are costs borne by the Owner to insure the value of assets in inventory from loss and/or damage.

## 6.3 Challenge Sessions

A series of workshops were conducted with Owner's SMEs and sponsor representatives to review the results of the benefits analysis. SMEs included representatives from I&C Maintenance Craft, I&C Maintenance Supervision, Maintenance Preparation (Scheduling and Planning), Work Management, Outage Management, Operations, and System Engineering. Sponsor representatives included Station and corporate leadership and capital project and finance management. The objectives of these sessions were to:

1. Provide SMEs and Owner's leadership with an overview of how data was collected, and benefits were calculated
2. Review key assumptions made and incorporate feedback into the analysis and resulting financial model
3. Verify that the quantified benefits were reasonable in nature and were the logical outcome of the analysis conducted.

At the end of these challenge sessions, participants indicated their understanding of the process followed and the rationality of the results obtained by that process as presented.

# 7. Financial Analysis and Valuation of BCA

Based on the methodology and insights described in previous sections, financial models were applied to provide the Owner with key metrics to evaluate the viability of the Project. The inputs to these models were the results of the analysis described in prior sections of this documents. The outputs included industry standard financial analytics, including the Project's NPV, IRR, and payback period.

## 7.1 Project Team Financial Model

A financial model was developed to incorporate one-time project costs associated with the Project as well as ongoing, incremental annual O&M costs over the plant's anticipated license period. The financial model utilized a discounted cash flow methodology. The model incorporated three central elements to determine financial metric outputs:

- One-time Project costs
- Recurring annual costs and benefits (and associated escalation rates)
- NPV of Project.

A description of each of these elements and how each were implemented in the Project Team's model is described in the following subsections.

### 7.1.1 One-Time Project Costs

The estimate of one-time installation and ongoing O&M costs associated with installing and operating the proposed modernized system were provided by the Owner to the Project Team. The estimates were based on parametrics and scaling of costs from similar modernization efforts conducted on non-safety related systems. The Owner also considered additional costs associated with licensing and engineering the Project to meet regulatory requirements. The estimates provided were based on the scope and benefits described in this research product based upon the design concept contained in INL/LTD-20-58490 [Reference 2] and have not been validated against a selected solution at this time. Future iterations of the BCA are expected to occur with conceptual design phase input from Owner and their selected vendor.

### 7.1.2 Recurring Annual Costs and Benefits

Recurring annual costs and benefits represent expected changes to the Station's O&M expenses (including carrying cost of inventory[5]) resulting from project implementation. These costs and benefits were estimated by the Project Team (as illustrated in prior sections) and are expressed in current year dollars.

### 7.1.3 Net Present Value of Project

**Determining Future Cash Flows**

As illustrated in prior sections of this research product, the Project Team analyzed Station data to determine the expected annual cost reductions for the current year and cast these benefits into future years utilizing escalation rates determined by the Project Team. These Future Cash Flows (FCF) resulting for labor and material benefits are calculated as follows:

$$(FCF_{Direct\ Labor})_n = (No.of\ Harvestable\ FTEs \times Annual\ Labor\ Rate) \times (1 + Escalation\ Rate)^n$$

$$(FCF_{Materials})_n = (Estimated\ Annual\ Benefit) \times (1 + Escalation\ Rate)^n$$

In a similar manner, FCFs can be forecast for other recurring benefits and costs, including outage contract labor, overtime savings, and carrying cost of inventory for each of the systems analyzed.

**Determining Present Value of Future Cash Flows**

Once expected cash flows from both one-time and recurring project costs and benefits have been tabulated in the financial model for each of the cost and benefit value streams, the PV (i.e., the value of the future cash flow in present dollars) for each of the value streams can be determined by discounting the FCF by a discount rate. In this case, the discount rate is equal to Owner's CoC. The CoC represents the lost opportunity for the Owner to place capital in alternative investments in lieu of this Project. The PV of each cash flow can be calculated as follows:

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5 For the purposes of this research product, expected recurring O&M costs associated with the modernized safety-related systems were provided by the Owner to facilitate the financial analysis. The Project Team did not participate in the development or analysis of the recurring O&M cost estimate.

$$PV_{Benefit(Cost)} = \sum_{n=0}^{n=Final\,Year} \frac{\left(FCF_{Benefit(Cost)}\right)_n}{(1 + Cost\ of\ Capital)^n}$$

Where:

$PV_{Benefit(Cost)} = Present\ Value\ of\ the\ Cash\ Flow\ Stream$

$FCF_{Benefit(Cost)} = Current\ Average\ Annual\ Material\ Expenditure$

$Cost\ of\ Capital = Cost\ of\ Capital\ (by\ Owner)$

$n = Nominal\ Year$

$Final\ Year = Year\ project\ lifecycle\ ends\ (defined\ by\ project\ team)$

**Determining Net Present Value**

To calculate the NPV of the Project, the Project Team summed the PV calculated for each cash flow stream:

$$NPV_{Project} = \sum PV_{Benefit(Cost)}$$

The resulting value can either be positive or negative, and the resulting implications of each of these values is explained in Table 2 below.

Table 2: Net Present Value outcomes and implications.

| If the NPV is … | Then the business case… |
|---|---|
| Positive (i.e., greater than or equal to zero) | Is favorable for the project investment. This implies that the project is expected to return more free cash to the utility as an investment, generating the Owner's CoC. |
| Negative (i.e., less than zero) | Is not favorable for the project investment. This implies that the project will return less free cash to the utility as an investment, generating the Owner's CoC. |

### 7.1.4 Internal Rate of Return

The IRR of a project is the Return on Capital (ROC) required for the NPV of the upgrade to be zero. It inverts the concept of an NPV calculation and instead calculates a project's ROC. This analysis enables the model to determine if the Project meets the utility's ROC requirements. How to consider an IRR analysis is outlined in the table below:

Table 3: Internal Rate of Return outcomes and implications

| If the IRR is … | Then the business case… |
|---|---|
| Positive (i.e., greater than or equal to cost of capital) | Is favorable for the project investment. This implies that the return of the project is greater than the utility's ROC. |
| Negative (i.e., less than zero) | Is not favorable for the project investment. This implies that the return of the project is less than the utility's ROC. |

### 7.1.5 Payback Analysis

To calculate the Project payback period, the Project Team started with the FCF at the initial investment period (Year 0). This value was negative due to upfront Project costs. Then, the Project Team cumulatively summed the FCFs for each following year. The payback period is calculated as the amount of time required for the cumulative sum of the FCFs to exceed zero.

This is sometimes referred to as a "break-even" analysis. Generally, a project can have multiple years of negative FCFs before having years of positive FCFs. It does not take into account any ROC rate and does not discount FCFs to their PV. As a result, FCFs after year 0 are inflated in a payback analysis compared to those in an NPV analysis. The representative payback analysis for this Project can be seen below in Figure 7.

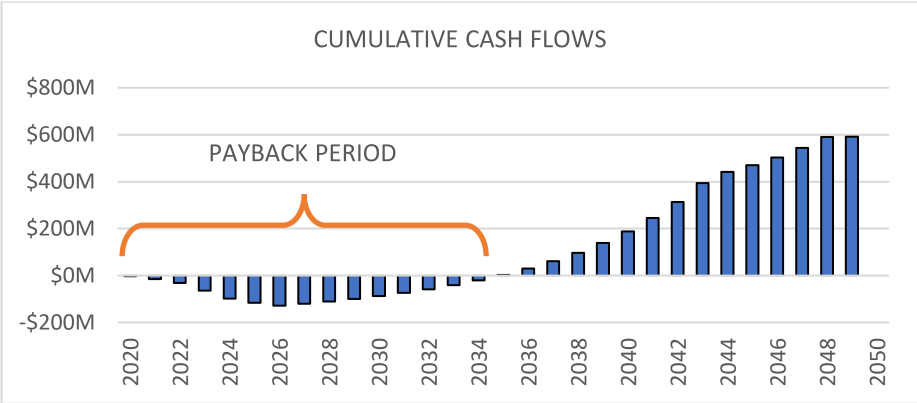


Figure 7: Illustration of cumulative cash flow chart on cost benefit analysis worksheet.

## 7.2 Demonstration of Electric Power Research Institute Business Case Analysis Model

EPRI has developed the Business Case Analysis Model (BCAM) financial model tool to evaluate the business cases of potential upgrades to power plants. It follows a similar methodology as the internal Project Team model in its use of one-time costs to implement a project, analysis of ongoing upgrade benefits and costs, discounting of FCF, and calculation of financial metric outputs like NPV, IRR, and payback period. The Project Team translated the internal model input data to EPRI BCAM inputs to both validate the results of the Project Team's financial model as well as validate the functionality of the BCAM model. Although the BCAM lacked some of the flexibility of the custom model produced internally by Project Team, both models produced similar financial results and conclusions about the viability of the Project and thereby validated the BCAM as a packaged option that subsequent utilities applying this methodology could employ to conduct the financial analysis of a similar modernization.

# 8. Summary of Results from Business Case Analysis

**NOTE: The figures provided in this section are intended to be illustrative and representative of an order of magnitude in scale of benefits identified by the research Project Team and are not intended to present material data utilized in the Owner's cost-benefit analysis.**

The summary results of the benefits analysis of the four safety systems yielded the potential for substantial annual cost savings as well as other indirect benefits of value to the Station. The overall results of the financial models employed yielded a positive business case for the Owner.

## 8.1 Direct Annual Benefits

Utilizing the approach and methodologies outlined in this research product, more than $4 million of direct annual benefits were identified as attributable to the modernization.

- Harvestable FTEs: An analysis of online workload reduction in ST, PM, and CM activities resulted in 8 to 12 harvestable FTEs.
- Outage Contract Resources: An analysis of outage workload reductions in ST and PM activities resulted in a reduction of 4000 to 6000 hours of I&C required support a typical outage.
- Material Expenditures: An analysis of material required to maintain and support current systems revealed the potential for $1.5 to $2.0 million in annual benefits.
- Overtime Labor: An analysis of unharvestable workload reductions (i.e., workload reductions not sufficient in quantity to yield an FTE resource) of resources eligible for overtime yielded potential for up to $100,000 in annual savings.

## 8.2 Indirect Benefits

Utilizing the approach and methodologies outlined in this product, additional indirect benefits and avoided costs were identified and considered in the overall business case.

- Workload Efficiencies: Up to 6,000 hours of additional workload efficiencies that can be utilized by the Station toward internal strategic objectives.
- Outage Support Efficiencies: Identified reduction to support fewer outage contract I&C resources (e.g., security, onsite training, briefs, etc.) as identified above.
- Avoided Cost of Obsolescence: Material costs for obsolete system components are increasing at exponential rates. The Project Team's analysis of these components revealed a PV of $50 to $200 million in avoided costs over the remaining lifecycle of the Station.
- Carrying Cost of Inventory: An analysis of current inventory of materials and spare components resulted in up to $900,000 in Owner's capital carrying cost.

## 8.3 Estimated Costs of Upgrade

The estimates of one-time installation and ongoing O&M costs associated with installing and operating the proposed modernized system were provided by the Owner to the Project Team. The estimates were based on parametrics and scaling of costs from similar modernization efforts conducted on non-safety related systems. The Owner also considered additional costs associated with licensing and engineering the Project to meet regulatory requirements. The estimates provided were based on the scope and benefits described in this research product and have not been validated against a selected solution. Costs presented are indicative of expected Project costs by the Owner and are considered within an order of magnitude of true costs.

The Owner's activity is a first-of-a-kind activity that impacts expected Project costs. This is reflected in the upper end of the range presented for capital cost and subsequent financial metrics presented in Section 8.4. It is expected that future safety-related I&C modernizations of a similar scope (i.e. a safety-related RPS, ECCS, N4S, and an ATWS Mitigation System) at a BWR will leverage the work products of this pilot as a roadmap, eliminating these first-of-a-kind costs. This elimination is reflected in the lower end of the range presented for capital costs and subsequent financial metrics presented in Section 8.4.

- Capital Costs: Between $70 to $120 million (two units)
- Ongoing O&M: $150,000 annually in labor and materials.

## 8.4 Business Case Analysis Aggregate Results

- NPV[6]: $50 to $80 million (positive business case over the lifecycle of the Station)
- Payback Period: 12 to 15 years
- Internal Rate of Return: 12% to 18%.

# 9. Subsequent Utility Implementers

It is envisioned that subsequent utility implementers interested in performing a BCA for a comparable modernization with cross-functional impacts as part of a larger digital transformation will follow a similar approach and utilize the methodologies and tools provided as part of this research product. Appendix A—Systematic Presentation of Business Case Analysis Process and Appendix B—Business Case Analysis Workbook are intended to provide a starting point for these efforts. In such cases, it is important that a qualified analyst familiar with financial modeling of complex projects be selected to lead the Project Team through the methodology. Engineers knowledgeable of the current design and the envisioned replacement systems are also necessary to bound the scope and identify potential areas of material and labor cost savings as a starting point. It is also necessary to work with SMEs to correct/validate these savings. While a significant level of detail is provided based on the work performed for this Project in this research product, the subsequent analyst should seek to modify or improve upon the techniques presented based on the availability and integrity of the base data available in the bottom-up approach.

# 10. References


1. Digital Instrumentation and Controls Interim Staff Guidance #06 (DI&C-ISG-06), Revision 2, "Licensing Process."
2. INL/LTD-20-58490, *Vendor-Independent Design Requirements for a Boiling Water Reactor Safety System Upgrade*
3. 10 CFR 50.62, "Requirements for reduction of risk from anticipated transients without scram (ATWS) events for light-water-cooled nuclear power plants"


[6] Generic cost of capital of 10% was used for the Net Present Value

# Appendix A: Systematic Presentation of Business Case Analysis (BCA) Process

# APPENDIX A:
# SYSTEMATIC PRESENTATION OF BUSINESS CASE ANALYSIS (BCA) PROCESS

# APPENDIX A
# SYSTEMATIC PRESENTATION OF BUSINESS CASE ANALYSIS PROCESS

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SAMPLE FIGURES PROVIDED IN THIS APPENDIX ARE FOR ILLUSTRATIVE PURPOSES AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA

# 1. INTRODUCTION

It is envisioned that subsequent utility implementers interested in preparing a business case analysis (BCA) will follow a similar approach and utilize the methodologies and tools provided as part of this research product. In such cases, it is important that a qualified analyst familiar with financial modeling of complex projects be selected to lead the Project Team through the BCA methodology, in tandem with other engineering, vendor selection, and licensing activities. Engineers knowledgeable of the current design and the envisioned replacement systems are also necessary to bound the scope and for identifying potential areas of material and labor cost savings as a starting point. It is also necessary to work with Subject Matter Experts (SMEs) to correct/validate these savings. While a significant level of detail is provided based on the work performed for this Project ("Business Case Analysis for Digital Safety-Related Instrumentation & Control System Modernizations"), the analyst should seek to modify or improve upon the techniques presented, based on the availability and integrity of the base data used in what is described as a bottom-up approach. This Appendix A, in conjunction with the sample job aids and templates provided in Appendix B, are intended to offer a starting point for the analyst's effort to compose the BCA.

In preparing a BCA for a transformative project with cross-functional implications, the analyst must consider both cost and benefits of the project to determine if the project is viable. Estimating project costs is a relatively straight-forward process that can often be appraised in early stages of the project using parametric methods and scaling of project data from completed analogous projects. As project scope is progressively elaborated, initial cost estimates are verified with vendor quotes for engineering, equipment supply, and construction. During implementation, project costs are actively monitored, and final costs are available for review as the project is turned over to operations.

Unlike methods to estimate project costs, methods to estimate project benefits are not well established. Parametric methods are unsuitable, as they are difficult to translate and scale from similar efforts, if they indeed exist. Historical source data required for such methods rarely exist as benefits are not realized until after the project has closed. Furthermore, benefits are difficult to verify unless cost reductions have been clearly translated into Operations and Maintenance (O&M) budget reductions in ways that are directly attributable to the project.

For these reasons, in order to present a fair comparison of project costs and benefits, it is recommended that the analyst consider building the benefits estimate using a "bottom-up" approach. In a "bottom-up" approach, the analyst seeks to model the impacts of the proposed project by collecting, synthesizing, and validating data from the lowest levels available (such as tasks performed by resources or equipment items maintained), and quantifying the cumulative impacts of labor and materials across various functions to arrive at an estimate of benefits.

The following sections describe in detail the systematic approach utilized by the Project Team to perform the BCA as part of this research product.[1]

1. The BCA results, which are limited to the development of a detailed cost-benefit analysis, are considered proprietary to the Owner and are provided in a limited distribution version of this research product. For this public version, financial data have been altered to protect the Owner's proprietary information. Sample data are intended to be illustrative and representative in scale, not to provide material data utilized in the Owner's financial analysis. The ultimate purpose of this public, non-proprietary version is to communicate the process and related business case tool to enable similar BCAs for digital upgrades throughout the industry. It is expected that this methodology can be abstracted and used for nearly any system upgrade.

## 1.1 Business Case Analysis Methodology

When initiating work on the BCA, the analyst must align the Project Team on the methodology to be applied to the work. Illustrated in Figure A-1 is the methodology adopted by the Project Team for this research product.

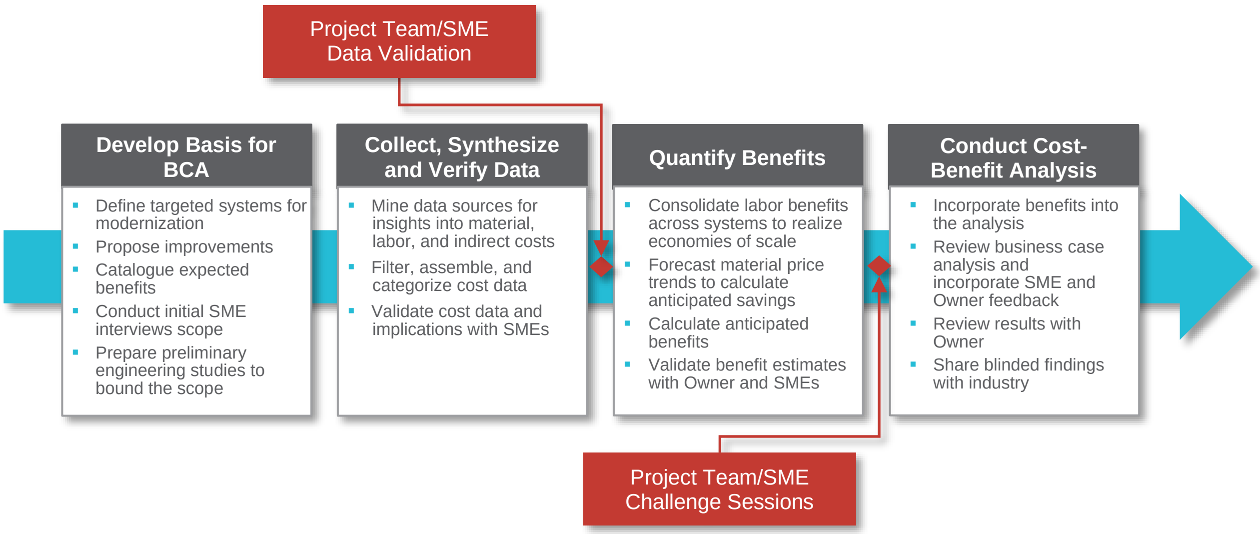


Figure A-1: Illustration of BCA methodology.

This methodology can be broken down into four steps:

1. Develop Basis for BCA:
   - Definitively bound the scope of current Instrumentation & Controls (I&C) systems envisioned for modernization
   - Propose system improvements and describe key features of modernization that may offer potential for financial benefit
   - Conduct initial interviews with SMEs to hypothesize potential reductions in labor and material costs enabled by identified system improvements/key features
   - Catalog expected benefits of the proposed digital modernization.
   - Prepare preliminary engineering studies and deliverables to support data collection activities
2. Collect and Synthesize Data:
   - Mine data sources that bound cost contributors related to the systems to be upgraded (such as historical material costs and trends, direct labor costs to maintain and support the systems, including surveillances, and indirect costs such as Corrective Action Program [CAP] activities)
   - Filter, assemble, and categorize cost data into workbooks
   - Apply enablers of quantifiable project benefits to the cost data to support validation
   - Present and validate cost data with SMEs to further identify existing system costs
3. Quantify Benefits:
   - Consolidating enabled workload reductions across existing systems to exploit features and economies of scale of the new digital systems and quantify harvestable labor benefits
   - Analyzing existing system historical data of purchased materials and expenditures to forecast avoided lifecycle costs enabled by the new digital systems

- Presenting and challenging benefit estimates with SMEs and management representatives to refine estimates based on expert judgement and achieve cross-functional consensus

4. Conduct Cost-Benefit Analysis:

   - Comparing costs to implement and operate the proposed modernized I&C systems to avoided costs (i.e., benefits) of maintaining current system
   - Present project metrics of Net Present Value (NPV), Internal Rate of Return (IRR), and payback period to Owner's leadership.

## 1.2 Business Case Analysis Charter

Prior to implementing the methodology described before, it is important for the analyst to organize project information while the BCA effort is being charted. Since representatives of multiple stakeholders may be involved in the BCA (e.g., finance, engineering, supply chain, licensing, and other Owner interests), it is important to agree on how the BCA will be developed as part of the overall project approach. The objectives during the chartering of the project are:

- Develop Initial Data Requests: Collect documentation required to initiate activities to define and clarify the project scope (in general terms) prior to meeting with the Project Team.
- Introduce Project Purpose and Objectives: Review initial scope documents and provide the assembled team with background and context. Describe the key objectives of the BCA as it relates to the broader project effort.
- Validate Project Team: Agree and document roles and responsibilities of parties and individuals assigned to the Project.
- Confirm Project Approach: Illustrate how the work is to be conducted, review the proposed methodology, and establish key milestones for project reviews and deliverables.
- Seek Agreement on BCA Deliverables: Describe the interim and final deliverables of the BCA and reach consensus with the Project Team on content and format to ensure the deliverables meet business requirements.
- Identify SMEs: Identify additional persons with subject matter expertise that can support and advise the project, validate data, and challenge deliverables.

## 1.3 Lessons Learned

Table A-1: Lessons Learned – Business case analysis methodology and charter.

| Number | Lesson Learned |
|---|---|
| 1-1 | Utilize a bottom-up method to estimate project benefits. Unlike methods to estimate project costs, methods to estimate project benefits are not well established. |
| 1-2 | It is important for the analyst to organize preliminary project information in preparation for an effective kick-off. |
| 1-3 | Developing a project charter that identifies roles and responsibilities of team members will ensure this is done. The Project Team should agree on how the BCA will be developed and align BCA activities with the broader scope to develop other aspects of the project. Other aspects and activities working in parallel with BCA might include system engineering studies, development of a License Amendment Request, stakeholder needs identification and vendor qualification. |

# 2. BOUNDING SCOPE AND DEVELOPING BASIS FOR BUSINESS CASE ANALYSIS

The objective during the initial step of the methodology is to bound the scope by developing and documenting the basis for the BCA. The analyst should guide the team to refine the scope to the resolution needed to build the BCA from the bottom up. In the case of the BCA developed for this research product, engineering studies were completed in order to define the scope down to the work task and equipment level to support mining and filtering of historical plant data.

## 2.1 Establish BCA Basis

The analyst must document the BCA basis to ensure the Project Team is aligned. The following documents are recommended to be documented early in the BCA, and maintained as the scope is progressively elaborated during project development:

- Description of Targeted Systems: Identifies and describes the physical nature and function of primary systems targeted for modernization
- Description of Proposed System Improvements: Describes the physical nature and key features of the proposed modernization
- Catalog of Expected Project Benefits: Describes how key features enable quantitative and qualitative benefits; an important step toward identifying SMEs and data sources that will be needed to estimate project benefits.

## 2.2 Perform Preliminary Engineering Activities

In order to collect baseline data to support the bottom-up approach, the analyst should engage with the team that is turned to the historical data available in the station's Work Management System (WMS). In early investigations into data availability for this research product, two findings were revealed:

1. As the engineering scope developed, the Project Team found that what was initially thought to be four safety systems extended into multiple subsystems that needed to be considered in the benefits analysis. A total of 20 plant systems were identified as impacted by the project.
2. The amount of historical data available from the WMS amounted to hundreds of thousands of records for each of the 20 plant systems examined.

In order to filter the volume of data being drawn from the WMS, the following preliminary engineering deliverables are necessary to efficiently sort the data for subsequent analysis.

In-Scope Equipment List: An engineering study of existing plant designs was conducted to identify and catalog plant equipment that would be impacted by the proposed project. This list was used to direct and limit data-mining activities to the in-scope systems identified. Refer to Appendix B—Sheet 1.1 for a sample template of an in-scope equipment list.

In-Scope System List: Production of the in-scope equipment list revealed that components impacted by the proposed project extended into several other plant systems (see Table A-2, below). The in-scope system list was created to direct the team to which systems needed to be examined among the approximately 100 engineered plant systems. Refer Appendix B—Sheet 1.2 for a sample in-scope system list template.

Table A-2: In-scope system list.

| Plant System Code | Primary System | Subsystem |
|---|---|---|
| 001 | N4S | Main Steam |
| 025 | N4S | Temp Monitoring |
| 026 | N4S | Radiation and Meteorological Monitoring System |
| 036 | ATWS Mitigation System | ATWS Mitigation System |
| 041 | ECCS | Main Steam/ADS |
| 042 | Common | Nuclear Boiler Instrumentation |
| 044 | N4S | Reactor Water Cleanup |
| 046 | RPS | Control Rod Drive |
| 048 | ATWS Mitigation System | Standby Liquid Control |
| 049 | ECCS | RCIC |
| 050 | ECCS | ADS |
| 051 | ECCS | RHR |
| 052 | ECCS | Core Spray |
| 055 | ECCS | HPCI |
| 056 | ECCS | HPCI |
| 059 | N4S | PCIG & TIP Power Supply |
| 071 | RPS | RPS |
| 072 | N4S | N4S |
| 076 | N4S | HVAC |
| 092 | ECCS | Emergency Diesel Generators |

Planned Maintenance Item (PMI) List: Planned maintenance work is typically managed at a station on a computer-based WMS. A PMI is created on the WMS to establish and track recurring work items that need to be performed, the frequency at which the work must be performed, and when the work must be completed. When a PMI indicates that an item is due to be performed, the work is scheduled and planned as a Work Order (WO). The WO serves to identify the resources and time allotted by station schedulers and planners to perform the work by a field crew. When a WO is completed, the Preventive Maintenance (PM) is satisfied and is reset to schedule the next instance the PMI must be performed. Each PMI received a unique identifier known at the participating station as a “PMID” (Planned Maintenance item Identifier). A list was produced by the station System Engineering group of all PMIs managed in the WMS. Refer to Appendix B—Sheet 1.3 for a sample template of a PMI list. This list included the following fields:

- PMID number
- PMI title
- PMI status (e.g., active/inactive/retired)
- PMI frequency code (a code that described both frequency and if the work was to be scheduled during an outage)

The PMI list was useful by the Project Team to:

- Filter historical WO data sourced from the WMS to those associated with active PMIs (i.e., filter out retired and inactive PMIs)[2] and ensure estimates of future workload reductions reflected the most recently established PMI frequencies
- To enable segregation of outage workload from online workload.

Surveillance and Test (ST) list: An engineering study was conducted to reconcile the station's Technical Specifications ("Tech Specs") required by its License Agreement to Surveillance and Test Procedures and the PMI list prior. The list enabled the team to cross-reference PMIs associated with ST Procedures. Refer to Appendix B—Sheet 1.4 for a sample template of an ST list.

## 2.3 Conduct Initial SME Interviews

Once SMEs have been identified during project initiation, the analyst coordinates a series of SME interviews with the Project Team present. This allows for an exchange of ideas about the project and helps to further develop basis documentation and identify additional benefits for the project. The analyst should consider scheduling SME interviews as cross-functional groups to allow for exchange of ideas.

Interview Guides: Prior to meeting with the SMEs, the analyst may provide the team with interview guides. Interview guides outline the order of discussions and list out key questions that need to be resolved. Enough time should be allowed for the Project Team to introduce the project scope and the SME to provide input in areas not anticipated by the team.

SME Interviews: With each interview, a lead should be selected to introduce project scope. The Project Team should then test the hypothesis of expected benefits and seek to identify data sources and SMEs to further clarify any discoveries.

## 2.4 Stage Data Collection

As preliminary engineering and SMEs input are obtained, the analyst should begin to stage for the data collection and consolidation activities in the next step of the methodology.

Update Basis Documentation: As scope is elaborated, it may be necessary to update basis documentation, particularly the catalog of expected project benefits.

Design and Plan BCA: For each item in the catalog of expected project benefits, the analyst should map out activities required to quantify the benefit (if quantifiable). The analyst may need to iterate this where the data, as desired, is unavailable and work out proxies with the Project Team when this occurs. Designing the BCA relies heavily on the analyst ability to research and display critical thinking skills during this time.

Prepare Data Requests: Based on information collected from the Project Team and SMEs, the analyst prepares data requests to support the BCA analysis. The analyst should seek out information from the station to understand the various work management, procurement, and financial systems that are available and where data may be found to support the BCA. The analyst should assess the integrity and reliability of the data where possible and seek alternatives, as necessary.

2. The station had undergone a cost-reduction effort where periodic maintenance on components was evaluated and reclassified to condition-based maintenance. As a result of this finding, the Project Team made efforts to filter out records linked to inactive or retired PMIs so as not to include this work in forecasting future workload reductions.

Frame Out BCA Workbook: Based on the design and plan to conduct the BCA, the analyst will begin to frame out a BCA workbook to consolidate and synthesize data collected as part of data mining exercises. A template workbook with limited samples of data have been provided in Appendix B to illustrate data collection and analytical techniques employed by the Project Team on this effort. As described in the introduction of this Appendix, the analyst should seek to modify and/or improve upon the tools and templates provided in Appendix B based on data available and practices preferred to achieve quantifiable results.

## 2.5 Lessons Learned

Table A-3: Lessons learned – Bounding scope and developing basis for BCA.

| Number | Lesson Learned |
|---|---|
| 2-1 | Hold preliminary scope discussions early in the project to help identify the safety-related I&C systems that are to be included in the modernization. |
| 2-2 | Consider utilizing a common system platform and examine modernization of multiple safety-related I&C systems as a single project to exploit economies of scale and identify quantifiable synergies generated by this approach. |
| 2-3 | Develop initial data requests by working backward by (a) documenting the desired result, (b) defining the analysis needed to calculate the result, and (c) identifying the data needed to support the analysis. |
| 2-4 | Conduct engineering studies to understand the full scope of the modernization at the level that data is being collected. As the engineering scope developed, the Project Team found that what was initially thought as four safety systems extended into multiple subsystems that needed to be considered in the benefits analysis. A total of 20 plant systems were identified as impacted by the project when detailed engineering studies were completed. |
| 2-5 | Develop methods to filter large amounts of data from the WMS. For this research, the amount of historical data available from the WMS amounted to hundreds of thousands of records for each of the 20 plant systems examined. Preliminary engineering deliverables identified and designed to enable the Project Team to filter the WMS data efficiently. |
| 2-6 | Investigate if the historical records can be used to establish future workload reductions. It was discovered during data collection that much of the WO historical record were linked to PMIs that were retired or out of service. The station had undergone a cost reduction effort where periodic maintenance on components was evaluated and reclassified to condition based maintenance. As a result, the Project Team made efforts to filter out records linked to retired or inactive PMIs so as not to include this work in forecasting future workload reductions. |

# 3. Estimation of Labor Benefits

This section describes an approach to estimating labor benefits utilized by the Project Team to produce the BCA for this research product. It outlines detailed methods and calculations employed to perform this BCA. Sample tools and templates are offered in conjunction with this description and are provided in *Appendix B*.

## 3.1 Estimating Labor Workload Reductions

To estimate labor workload reductions, the Project Team first looked at equipment affected by the modernization (i.e., equipment that would be replaced or otherwise dispositioned by this project) and created an in-scope equipment list. Historical records were then mined from plant data systems to determine current annual workload associated with the in-scope equipment. In general, O&M activities related to equipment can be classified into two types: planned work and unplanned work.

Planned work is generally managed using a computerized system. For example, as part of a station maintenance program, planned maintenance is managed on a WMS. To ensure activities are performed, a PMI is created in the WMS that broadly describes the work that needs to be performed and at what frequency it must be performed. Each PMI is assigned a unique identifier, or PMID. As PMIs become due, the WMS informs maintenance schedulers and planners that a WO needs to be created in the WMS to assign resources, order parts, and complete the work. Once the work is completed and closed, the PMI is satisfied and reset to establish the next required instance of work. Because the work is planned, the annual workload can be estimated accurately. Examples of planned work activities that can be forecast in this manner include:

- Surveillance and Test Work Orders
- Preventative Maintenance Work Orders
- Training program activities.

Unplanned work is managed differently from planned work. WOs are triggered by an observed condition, incident, or event that has occurred rather than from a PMI. In these cases, the event is evaluated, and a WO is created to correct the cause of the condition or event. Because the nature of the work is unplanned, annual workload can only be estimated by trending observed workload in the past and extrapolating that workload into the future. Examples of unplanned work activities that can be trended in this way include:

- Corrective Maintenance (CM) WOs
- Event management and corrective action program activities
- System Engineering support (e.g., troubleshooting system faults and anomalies).

### 3.1.1 Initial Data Acquisition

Labor workload reductions associated with in-scope equipment identified by system engineering were identified by examination of historical records sourced from the station's WMS. The Project Team designed a custom report with Information Technology (IT) support and downloaded historical WO at the task level. Reports were run for each of the systems identified in the in-scope system list. The downloaded files were voluminous, some containing hundreds of thousands of records dating back over 30 years. The resulting records were then filtered down to a manageable list of WO tasks performed by station resources. The key fields utilized in this data acquisition exercise are:

- System Code – This is used to identify the work with an engineering system made part of the WMS database. The Project Team identified 20 plant systems as in-scope to the modernization. Each in-scope system code linked to one of the four primary systems using the in-scope system list apart from "common instrumentation." Field instrumentation in this system could not be attributed to any one safety-related system. Workload reductions associated with common instrumentation were evaluated as an independent system.

- Unit Number – The team analyzed data for one of the station's two units with the practical assumption that the benefits would be identical for both units. This decreased the amount of raw data to analyze by half.
- Planned Maintenance Identification (PMID) Number – The PMID is a unique identifier assigned to track recurring planned maintenance in the WMS. This number was compared to the In-Scope PMI list. WOs associated with retired PMIs or legacy inactive PMIs with no due date were filtered out.
- Work Order Type – The WMS maintained several WO types. The team focused on work orders that were identified as PM WOs (which included preventive maintenance activities and ST activities) and CM WOs.
- Work Order Number – The unique identifier assigned to each managed package of work.
- Work Order Description – A brief description of the WO, sometimes indicating the equipment sub-components being maintained.
- Job Status (Open/Closed) – This indicates whether the WO was completed or not. The team only examined WOs that were closed (i.e., open WOs were filtered out).
- Work Order Task Number – Each WO contains any number of discrete tasks to be executed by resources. This is the lowest level of work (i.e., the highest level of granularity), available in the WMS. These tasks are afforded a sequential tracking number.
- Work Order Task Title – A brief description of the task performed.
- Work Order Status Date – The last time the work order was modified or updated in the WMS. The team utilized this field to limit the data analyzed to the last 15 years. (The data was further reduced to a 5-year period as part of data mining described in Section 3.1.2 below.)
- Equipment Number – A unique identifier assigned by the engineer of record to equipment that is common to both engineering and design documentation and plant systems such as the WMS. This number was compared to the in-scope equipment list. Equipment not in scope were filtered out.
- Equipment Name – A brief description of the equipment.
- Equipment Type –Equipment categorized into types that correlated with engineering disciplines in the design of the plant. The team utilized this field to filter out mechanical, process and piping equipment, and focused solely on work orders related to instrument and electrical equipment. This reduced the volume of raw data to examine by approximately 75%.
- Resource Code – Identifies the type of resource utilized (e.g., I&C maintenance craft, equipment operator, reactor operator, etc.) and that was utilized by the team to estimate workload reductions by resource type.
- Staff Required – Used in the calculation of workload associated with the WO task.
- Hours per Person – Used in the calculation of workload associated with the WO task.

### 3.1.2 Data Mining of Raw Labor Data

Once the raw labor data was obtained and subjected to initial screening, the resulting data set was mined using data provided in the preliminary engineering deliverables to create three data files described below:

- Surveillance and Test Data File – ST activities are planned maintenance tasks required by the station's technical specifications that are made part of the station's license agreement. The raw data files sourced from the WMS for each system were mined for WOs that were included on the ST List. The resulting data from each of the 20 subsystems were then consolidated into a single data file that provided a historical record of WO tasks as well as historical resource and expended effort data to complete in-scope ST activities over the past 5 years.

- Preventative Maintenance Data File – PMs are planned maintenance activities that are part of the station’s equipment reliability program. The raw data files sourced from the WMS for each system were mined for WOs that were included on the PMID List described in Section 2.2 above as “active” (i.e., inactive or retired PMs were excluded). The mined data were then filtered to remove PMID that were also included on the ST List so as not to replicate these activities in both lists. The remaining data from each of the 20 subsystems were then consolidated into a single data file and filtered further to include only tasks that were tied to equipment included in the in-scope equipment list described in Section 2.2, above. The resulting data file provided a historical record of WO tasks as well as historical resource and expended effort data to complete in-scope PM activities over the past 5 years.
- Corrective Maintenance Data File – CM activities are unplanned maintenance tasks required to be performed to support continuity of operations and in response to station observations and/or incident reports. The raw data files sourced from the WMS for each system were mined for WOs that were tagged as CM work orders in the WMS System. The data were then filtered to omit data not included on the in-scope equipment list described in Section 2.2, above. The remaining data from each of the 20 subsystems were then consolidated into a single data file that provided a historical record of WO tasks performed to execute CM activities over the past 5 years.

### 3.1.3 Surveillance and Test (ST) Workload Reduction Worksheet

#### *3.1.3.1 Synthesis of ST Workload Reduction Data*

To develop an estimate of expected ST workload reductions attributable to the proposed modernization, information from the ST List was synthesized with historical labor data from the ST Data File onto a single worksheet as illustrated in Figure A-2, below. A template of this worksheet has been provided in Appendix B—Sheet 2.1 of this research product.

*The resulting worksheet can be thought of as having two parts linked by a PMID Number:*

| PMI LEVEL DATA | | | | | | | | | ST WO TASK LEVEL DATA | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Tech Spec | ST No. | PMI Description | PMID No. | No. of PMIs | PMI Frequency (Annual) | Total PMI per Year | Online or Outage | System | Online or Outage | No. of PMIs with Task | PMI Frequency (Annual) | No. Times Task Performed | Task Description | Task included in ST WO | Functional Area | Work Group | Resource Type | No. Resource Req'd | Task Duration (Hrs) | Task Workload (Resource-Hrs) | Annual Workload (Resource-Hrs) | % Workload Reduction (Estimated) | Annual Workload Reduction (Resource-Hrs) | Other comments |
| 1.0. | RPS | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1. | T.4.3.1-1.3 | High Steam Dome Pressure | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1.1. | T.4.3.1-1.3 | ST-2-042-645-* | High Steam Dome Pressure Function | 243199 | 4 | 2 | 8 | Online | RPS | Online | 4 | 2.00 | 1 | Field Work | Y | MA | I&C | Craft | 2.00 | 1.00 | 2.00 | 16.00 | 100% | 16.00 | |
| | | ST-2-042-646-* | | 243201 | | | | | RPS | Online | 4 | 2.00 | 1 | Scheduling | N | MA | Maint Prep | Scheduler | 1.00 | 1.00 | 1.00 | 8.00 | 100% | 8.00 | |
| | | ST-2-042-647-* | | 243203 | | | | | RPS | Online | 4 | 2.00 | 1 | Work Planning/Coord. | N | WM | Maint Prep | Planner | 1.00 | 1.00 | 1.00 | 8.00 | 100% | 8.00 | |
| | | ST-2-042-648-* | | 243205 | | | | | RPS | Online | 4 | 2.00 | 1 | Print Out Procedures | N | MA | I&C | Clerical | 1.00 | 0.13 | 0.13 | 1.00 | 100% | 1.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | Load into EWP | N | MA | I&C | Supervisor | 1.00 | 0.13 | 0.13 | 1.00 | 100% | 1.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | Pre-Job Brief/Prep | N | OP | Shift Ops | SRO | 1.00 | 0.25 | 0.25 | 2.00 | 100% | 2.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | Pre-Job Brief/Prep | N | OP | Shift Ops | RO | 1.00 | 0.25 | 0.25 | 2.00 | 100% | 2.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | WO Closeout | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 2.00 | 100% | 2.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | Grade ST | N | MA | Maint Prep | Supervisor | 1.00 | 0.25 | 0.25 | 2.00 | 100% | 2.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | Maintain Records | N | MA | Maint Prep | Clerical | 1.00 | 0.25 | 0.25 | 2.00 | 100% | 2.00 | |

PMI Level Data | ST WO Task Level Data

Figure A-2: Illustration of ST workload reduction worksheet.

1. ***Planned Maintenance Item-Level Data*** –Provides information on the ST to be performed and how often it is performed. Similar STs (i.e., STs that were identical with the exception that STs were scheduled separately for each of the instrument signal channels) were combined to reduce repetition. The fields in this partition include:
   - Technical Specification Number – Reference to the technical specification requirement that mandates the work as part of the station’s operating license.

- Surveillance and Test Number – A reference to the ST procedure that provides detailed instruction of how to perform the work.
- Planned Maintenance Item Description – A brief description of the ST work to be performed (i.e., a title for the work).
- Planned Maintenance Identification Number – A unique identifier assigned to track recurring planned maintenance in the WMS. Each PMI is assigned a PMID for tracking in the WMS and is the key linking data field to the ST WO.
- Number of Planned Maintenance Items – Indicates the number of PMIs associated with the ST. (Similar STs were grouped together to reduce repetition and for ease of analysis. For example, if the High-Steam Dome-Pressure Function Test involved four channels per unit, there would be four similar STs identified for each unit. The Project Team grouped these together as the workload and frequency are identical.)
- Planned Maintenance Item Frequency (Annual) – How often the PM must be performed. This field is manually entered based on the frequency code provided by the PMID List. It is expressed in the number of times per year.
- Total Planned Maintenance Items per Year – This value is calculated as the product of [*Number of PMIs*] and [*PMI Frequency*].
- Online or Outage – Binary indicator of whether the PM is scheduled during an outage or allowed to be performed online.

2. ***Surveillance and Test Work Order Task-Level Data*** **-** Sourced from the WMS and linked to the PMI-Level Data through a common PMID. Where multiple PMIs were grouped (e.g., multiple channels for the same test), the ST WO Task Level provided is representative of multiple historical WO's examined. This data was later subjected to validation by maintenance craft, supervisors, planners, and schedulers. The fields include:

   - System – System is the primary system (e.g., Reactor Protection System [RPS], Emergency Core Cooling System [ECCS], Nuclear Steam Supply Shutoff System [N4S]). This allows the work reductions identified to be credited one of the primary systems when summarizing workload reductions.
   - Online or Outage – Online or Outage is repeated at the Task Level from the prior PMI Level Data. It is utilized at the task level as a filter when summing workload reductions.
   - Number of Planned Maintenance Items with Task – Generally repeated from the number of PMIs field listed in the PMI-Level Data, utilized to calculate Annual Workload Reduction. In some cases, this number needed to be adjusted during validation to add or subtract activities associated with certain PMIs in the grouping and not others. These cases were rare.
   - Planned Maintenance Items Frequency (Annual) – Repeated from the PMI-Level Data above and utilized to calculate Annual Workload Reductions (see below).
   - Number of Times Task Performed – In some instances where a task is performed multiple times within the same WO (e.g., task closeout by supervisor), the analyst can indicate it here rather than repeat entry of the task. It is utilized to calculate Annual Workload Reductions (see below).
   - Task Description – A brief description of the task performed within the ST WO.
   - Task Included in Surveillance and Test Work Order – A binary indication (Y/N) if a task was sourced from WMS or added through SME interviews and data-validation exercises performed later.
   - Functional Area (FA) – The area the assigned Resource Type belongs to. This data field is utilized to align the data with FA provided in the Electric Power Research Institute (EPRI) BCAM model. However, an analyst may assign FA that is aligned with the station's organization chart. FA was utilized as a sorting function when summing data into various resource categories

and allowed the Project Team to examine workload reductions across departments within the same function. A list common functional areas as well as their corresponding acronyms, workgroups, and resource types is in Table A-4 (below).

- Work Group – Assigned to the resource type (refer to Table A-2 above) by the analyst based on review of the station's organization chart. Work Group was utilized as a sorting function when summing data into various resource categories and allowed the team to combine or segregate organizational impacts of workload reductions between groups.
- Resource Type – A description of the resource assigned to a WO Task. A simplified list for resource types was utilized to assign work to specific resources (e.g., I&C Maintenance Craft, Administrative Assistant, Scheduler, Planner, etc.)[3]
- Number of Resources Required – Provides the number of like resources that are needed/required to perform a task and is used to calculate Task Workload.
- Task Duration (Hours) – The number of hours the scheduler has planned to complete the task. Task Duration is used to calculate Task Workload.
- Task Workload (Resource Hours) – Indicates the total hours needed to complete a task line item and is calculated as the product of [*Number of Resources Required]* and [*Task Duration]*.
- Annual Workload (Resource Hours) – The Annual Workload Reduction reached by accounting for the frequency assigned to the PMI. It is calculated as the product of [*No of PMIs with Task*], [*PMI Frequency*], [*Number of Times Task is Performed per ST WO*], and [*Task Workload*].
- Workload Reduction (%) – Workload reduction is the estimated percentage the Task Workload is expected to be reduced through the modernization effort. A 100% workload reduction indicates the task is completely eliminated. Lower percentages indicate some level of the task is expected to remain after the modernization is complete. For example, a digitally modernized system may greatly simplify a required ST, but the ST may still be required to fulfill the station's Tech Spec requirements.
- Annual Workload Reduction – The Annual Workload Reduction indicates the total workload reduction expected as a result of the modernization, annualized based on the PMID frequency. It is calculated as the product of [*Annual Workload (Resource Hours)*] and [*Workload Reduction (%)*].

Table A-4: Common functional areas and corresponding work groups and resources.

| Labor Category | | |
|---|---|---|
| **Functional Area (FA) (aligned with EPRI BCAM)** | **Work Group (aligned with station Org Chart)** | **Resource Type** |
| Maintenance (MA) | I&C Maintenance | Supervisor |
| | | Craft |
| | | Clerical |
| | Electrical Maintenance | Supervisor |
| | | Craft |
| | | Clerical |
| | Mechanical Maintenance | Craft |
| | Maintenance Support | Craft |
| | Component Maintenance (CMO) | Technician |

3. The resource types identified in the WMS were inconsistent. The team developed a simplified list of resource types to consolidate like resources into a single category.

| Labor Category | | |
|---|---|---|
| **Functional Area (FA) (aligned with EPRI BCAM)** | **Work Group (aligned with station Org Chart)** | **Resource Type** |
| | Reactor Services | Technician |
| | Maintenance Prep | Supervisor |
| | | Scheduler |
| | | Clerical |
| Work Management (WM) | Maintenance Prep | Planner |
| | Outage Management | Scheduler |
| | | Planner |
| Operations (OP) | Shift Operations | Senior Reactor Operator (SRO) |
| | | Reactor Operator (RO) |
| | | Equipment Operator (EO) |
| | Operations Support | Scheduler |
| | Operations Services | Planner |
| | | Clerical |
| | Reactor Engineering | Engineer |
| Engineering (EN) | System Engineering | Supervisor |
| | | Engineer |
| Radiation Protection (RP) | Support | Technician |
| Chemistry (CY) | Chemistry | Technician |
| Corrective Action Program (CA) | Various | Various |
| Training (TR) | Operations | Various |
| | Maintenance | Various |
| Information Technology (IT) | IT | Analyst |

### 3.1.4 Validation of ST Workload Reduction Data

The team conducted a series of SME validation sessions to review the data and make any adjustments necessary. The validation sessions included SMEs from engineering, operations, maintenance, and work management by:

- Providing an overview on how the data was collected and compiled.
- Providing an opportunity to make necessary adjustments to the data based on SME experience. For example, there might be wide discrepancies in the resources and time required on various WOs examined.
- Identifying additional support tasks not identified on the WOs. For example, the work order will identify tasks and field resources necessary to perform a test, and occasionally key support activities from operations, but they generally do not identify time spent scheduling, coordinating, and supervising the work. These tasks were added manually by the team with SME input.
- Confirming the summary data was directionally correct and reasonably aligned with their experience.

### 3.1.5 Consolidation of ST Workload Reduction Data

Once validation is complete, the WO Task Level Data can be consolidated in several ways useful to the Project Team. Figure A-3 (see below) provides an example of how the ST workload reductions may be summarized for a system.

Figure A-3 demonstrates how the team aggregated data into categories useful to the project:

- Workload reductions can be grouped by FA, work group, or resource type depending on what the team is trying to achieve.
- Impacts to online workforce and outage workforce can be evaluated separately.
- Summary statistics can be developed and compared to other systems.

A template to summarize ST labor workload reductions have been provided in Appendix B—Sheet 2.4 of this research product.

**Annual Workload Reduction (Hrs.) by Labor Category (2 Units)**

| Labor Category | | | System 1 | | System 2 | | System 3 | | System 4 | | Common | | Total Hrs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Functional Area | Work Group | Resource Type | Online Workload Reduction | Outage Workload Reduction | Online Workload Reduction | Outage Workload Reduction | Online Workload Reduction | Outage Workload Reduction | Online Workload Reduction | Outage Workload Reduction | System 042 Workload Reduction | Shift Rounds Workload Reduction | |
| MA | I&C | Supervisor | 114.00 | 3.00 | | | | | | | | | 117.00 |
| MA | I&C | Craft | 1,336.24 | 500.60 | | | | | | | | | 1,836.84 |
| MA | I&C | Clerical | 38.00 | 1.00 | | | | | | | | | 39.00 |
| MA | Electrical | Supervisor | - | - | | | | | | | | | - |
| MA | Electrical | Craft | - | - | | | | | | | | | - |
| MA | Electrical | Clerical | - | - | | | | | | | | | - |
| MA | Mechanical | Craft | - | - | | | | | | | | | - |
| MA | Support | Craft | - | - | | | | | | | | | - |
| MA | CMO | Technician | - | - | | | | | | | | | - |
| MA | Reactor Services | Technician | - | - | | | | | | | | | - |
| MA | Maint Prep | Supervisor | 76.00 | 2.00 | | | | | | | | | 78.00 |
| MA | Maint Prep | Scheduler | 329.34 | - | | | | | | | | | 329.34 |
| MA | Maint Prep | Clerical | 76.00 | 2.00 | | | | | | | | | 78.00 |
| WM | Maint Prep | Planner | 329.34 | - | | | | | | | | | 329.34 |
| WM | Outage Mgmt | Scheduler | - | 18.50 | | | | | | | | | 18.50 |
| WM | Outage Mgmt | Planner | - | 13.50 | | | | | | | | | 13.50 |
| OP | Shift Ops | SRO | 76.00 | 2.50 | | | | | | | | | 78.50 |
| OP | Shift Ops | RO | 108.00 | 4.80 | | | | | | | | | 112.80 |
| OP | Shift Ops | EO | 64.00 | 13.10 | | | | | | | | | 77.10 |
| OP | Support | Scheduler | - | - | | | | | | | | | - |
| OP | Services | Planner | - | - | | | | | | | | | - |
| OP | Services | Clerical | - | - | | | | | | | | | - |
| OP | Reactor Eng | Engineer | - | - | | | | | | | | | - |
| EN | Syst Eng | Supervisor | - | - | | | | | | | | | - |
| EN | Syst Eng | Engineer | - | - | | | | | | | | | - |
| RP | Support | Technician | - | - | | | | | | | | | - |
| CY | Chemistry | Technician | - | - | | | | | | | | | - |
| CA | Various | Various | - | - | | | | | | | | | - |
| TR | Ops | Various | - | - | | | | | | | | | - |
| TR | Maint | Various | - | - | | | | | | | | | - |
| IT | IT | Analyst | - | - | | | | | | | | | - |
| **TOTAL:** | | | **2,546.92** | **561.00** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **3,107.92** |

Check: 3,107.92 OK

**Summary Statistics (2 Units)**

| Summary Statistic | System 1 | System 2 | System 3 | System 4 | Common | Total |
|---|---|---|---|---|---|---|
| No. of In-Scope PMI Identified | 34 | | | | | 34 |
| No. PMI Performed per Year | 17 | | | | | 17 |
| Total In-Scope Annual Workload | 632 | | | | | 632 |
| Average Labor Hours per ST WO* | 37 | | | | | 37 |
| Labor Benefits Identified (Reduced Workload) | 561 | | | | | 561 |
| **Percent Workload Reduction** | **89%** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **89%** |

* Total Average Labor Hours per ST WO excludes Shift Rounds (Common)

Figure A-3: Illustration of ST workload reduction summary worksheet.

### 3.1.6 Preventive Maintenance (PM) Workload Reduction Worksheet

#### *3.1.6.1 Synthesis of PM Workload Reduction Data*

To develop an estimate of expected PM workload reductions attributable to the proposed modernization, the Project Team used a process similar to the one used for ST workload reductions. The team consolidated information from the PMI list with historical labor data from the PM data file onto a single worksheet is illustrated in Figure A-4 below.

| PMI LEVEL DATA | | | | | | | | | PM WO TASK LEVEL DATA | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Equipment Type | PMI Description | Equipment Number | PMID No. | No. of PMIs | PMI Frequency (Annual) | Total PMI per Year | Online or Outage | System | Online or Outage | WO Task No. | No. of PMIs with Task | PMI Frequency (Annual) | No. Times Task Performed | Task Description | Task included in PM WO | Functional Area | Work Group | Resource Type | No. Resource Req'd | Task Duration (Hrs) | Total Task Labor (Hrs) | Total Time (Annual) | % Workload Reduction (Estimated) | Annual Workload Reduction (Resource-Hrs) | Other comments |
| 1.0 RPS | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1. Routine Relay Replacement | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1.1. | Instrument | Routine Relay Replacement | C71A-K03C | 219474 | 36 | 0.025 | 0.88 | Outage | RPS | Outage | 1 | 36 | 0.025 | 1.00 | Pre-outage Bench Calibration | Y | MA | I&C | Craft | 1.00 | 4.00 | 4.00 | 3.60 | 100% | 3.60 | |
| | | | C71A-K01A | 219475 | | | | | RPS | Outage | 2 | 36 | 0.025 | 1.00 | Replacement | Y | MA | I&C | Craft | 2.00 | 6.00 | 12.00 | 10.80 | 100% | 10.80 | |
| | | | C71A-K01B | 219476 | | | | | RPS | Outage | 3 | 36 | 0.025 | 1.00 | Perform Test | Y | MA | I&C | Craft | 2.00 | 6.00 | 12.00 | 10.80 | 100% | 10.80 | |
| | | | C71A-K01C | 219477 | | | | | RPS | Outage | 4 | 36 | 0.025 | 1.00 | Update Component Record Label | Y | WM | Maint Prep | Planner | 2.00 | 4.00 | 8.00 | 7.20 | 100% | 7.20 | |
| | | | C71A-K01D | 219478 | | | | | RPS | Outage | | 36 | 0.025 | 1.00 | WO Task Closeout | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 0.23 | 100% | 0.23 | |
| | | | C71A-K03A | 219479 | | | | | RPS | Outage | 5 | 36 | 0.025 | 1.00 | Pre-outage Tech Review | Y | MA | I&C | Craft | 1.00 | 16.00 | 16.00 | 14.40 | 100% | 14.40 | |
| | | | C71A-K03B | 219480 | | | | | RPS | Outage | 6 | 4 | 0.025 | 1.00 | Stage Equipment | Y | MA | I&C | Craft | 2.00 | 8.00 | 16.00 | 1.60 | 100% | 1.60 | |
| | | | C71A-K03D | 219481 | | | | | RPS | Outage | 7 | 4 | 0.025 | 1.00 | Build Non-Conductive Platform | Y | MA | Support | Craft | 2.00 | 24.00 | 48.00 | 4.80 | 100% | 4.80 | |
| | | | C71A-K03E | 219482 | | | | | RPS | Outage | 8 | 8 | 0.025 | 1.00 | APRM1 Time Response PMT (C71A-K12A thru H) | Y | MA | I&C | Craft | 2.00 | 6.00 | 12.00 | 2.40 | 100% | 2.40 | |
| | | | C71A-K03F | 219483 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | Pre-Job Brief | N | OP | Shift Ops | RO | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K03G | 219484 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | Pre-Job Brief | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K03H | 219485 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | WO Task Closeout | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K08A | 219486 | | | | | RPS | Outage | 9 | 8 | 0.025 | 1.00 | OPRM1 Time Response PMT (C71A-K12A thru H) | Y | MA | I&C | Craft | 2.00 | 6.00 | 12.00 | 2.40 | 100% | 2.40 | |
| | | | C71A-K08B | 219487 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | Pre-Job Brief | N | OP | Shift Ops | RO | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K08C | 219488 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | Pre-Job Brief | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K08D | 219489 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | WO Task Closeout | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K10A | 219490 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | Scheduling and Coordination | N | MA | Maint Prep | Scheduler | 1.00 | 1.00 | 1.00 | 4.50 | 100% | 4.50 | |
| | | | C71A-K10B | 219491 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | Print Out Procedures (Tasks 1-3, 5, 7) | N | MA | I&C | Clerical | 1.00 | 0.50 | 0.50 | 2.25 | 100% | 2.25 | |
| | | | C71A-K10D | 219492 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | Load into EWP (Tasks 1-3, 5, 7) | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 1.13 | 100% | 1.13 | |
| | | | C71A-K10D | 219493 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | Pre-Job Brief (Tasks 1-3, 5, 7) | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 1.13 | 100% | 1.13 | |
| | | | C71A-K10E | 219494 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | Pre-Job Brief (Tasks 1-3, 5, 7) | N | OP | Shift Ops | RO | 1.00 | 0.25 | 0.25 | 1.13 | 100% | 1.13 | |
| | | | C71A-K10F | 219495 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | WO Task Closeout (Tasks 1-3, 5, 7) | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 1.13 | 100% | 1.13 | |
| | | | C71A-K10G | 219496 | | | | | RPS | Outage | | 36 | 0.025 | 1.00 | Ops Support/Review | N | OP | Shift Ops | RO | 1.00 | 0.50 | 0.50 | 0.45 | 100% | 0.45 | |
| | | | C71A-K10H | 219497 | | | | | RPS | Outage | | 36 | 0.025 | 1.00 | Ops Support/Review | N | OP | Shift Ops | SRO | 1.00 | 0.50 | 0.50 | 0.45 | 100% | 0.45 | |
| | | | C71A-K12A | 219498 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12B | 219499 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12C | 219500 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12D | 219501 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12E | 219502 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12F | 219503 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12G | 219504 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12H | 219505 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K33A | 225516 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K33B | 225517 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K33C | 225518 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K33D | 225520 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | | | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | | | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | | | | | | | | | | | | | | | | | | | | | -- | | -- | |
| 1.2. Agastat Relay Replacment | | | | | | | | | | | | | | | | | | | | | | | | | | |

PMI Level Data — WO Task Level Data

Figure A-4: Illustration of PM labor workload reduction worksheet.

A template of this worksheet is provided in Appendix B—Sheet 2.2 of this research product. The resulting worksheet can be thought of as having two levels of data:

1. *PMI Level Data*– The data was sourced from the PMI list. This data provides information on the PMI to be performed and how often it is performed. Similar PMs (i.e., PMs that were for similar components such as relays or contacts) were combined to reduce repetition. The fields in this partition include:

   - Equipment Type – Categorized the equipment into types that correlated with engineering disciplines in the design of the plant. The team utilized this field to filter out mechanical, process and piping equipment, and focused solely on work orders related to instrument and electrical equipment. This reduced the volume of raw data to examine by approximately 75%.
   - Planned Maintenance Items Description – PMI Description provides a brief description of the work to be performed (i.e., a title for the work).
   - Equipment Number – A unique identifier assigned by the engineer of record to equipment that is common to both engineering and design documentation and plant systems such as the WMS. This number was compared to the in-scope equipment list. Equipment not in scope were filtered out.
   - Planned Maintenance Items Identification Number – A unique identifier assigned to track recurring planned maintenance in the WMS. Each PMI is assigned a PMID for tracking in the WMS and is the key link to the PM WO Task-Level Data below.
   - Number of Planned Maintenance Items – Associated with the equipment. As noted above, PMs were similarly grouped together to reduce repetition and for ease of analysis.
   - Planned Maintenance Items Frequency (Annual) – Indicates how often the PMI must be performed.
   - Total Planned Maintenance Items per Year – This value is calculated as the product of [*Number of PMIs*] and [*PMI Frequency*].
   - Online or Outage – A binary indicator of whether the PMI is scheduled during an outage or allowed to be performed online.
   - *Preventive Maintenance Work Order Task Level Data*– Data sourced from the PM Data File and used to calculate expected workload reductions. The fields include:
   - System – The primary system (e.g., RPS, ECCS, N4S) this task is credited to for the purposes of summarizing workload reductions attributed to the system.

- Online or Outage – Repeated at the Task Level from the prior PMI Level Data. It is utilized at the task level as a filter when summing workload reductions.
- Number of Planned Maintenance Items with Task – Generally repeated from the number of PMIs field the PMI Level Data and is utilized to calculate Annual Workload Reduction below. In some cases, this number needed to be adjusted during validation to add or subtract activities associated with certain PMIs in the grouping and not others. These cases were rare.
- Planned Maintenance Items Frequency (Annual) – Repeated from the PMI Level Data and utilized to calculate Annual Workload Reductions.
- Number of Times Task Performed – In some instances where a task is performed multiple times within the same WO (e.g., task closeout by supervisor), the analyst can indicate it here rather than repeat entry of the task. It is utilized to calculate Annual Workload Reductions.
- Task Description – A brief description of the task performed within the ST WO.
- Task Included in Surveillance and Test WO – A binary indication (Y/N) if a task was sourced from WMS or was added through SME interviews and data validation exercises performed later.
- Functional Area – The area to which the assigned Resource Type belongs. This data field is utilized to align the data with FA provided in Electric Power Research Institute (EPRI) BCAM model. However, an analyst may assign FA that is aligned with the station's organization chart. FA was utilized as a sorting function when summing data into various resource categories and allowed the Project Team to examine workload reductions across departments within the same function. A list common FAs as well as their corresponding acronyms, workgroups, and resource types is in Table A-4 in the prior section.
- Work Group – Assigned to the Resource Type (refer to Table A-4, above) by the analyst based on review of the station's organization chart. Work Group was utilized as a sorting function when summing data into various resource categories and allowed the team to combine or segregate organizational impacts of workload reductions between groups.
- Resource Type – A description of the resource assigned to a WO Task. A simplified list for resource types was utilized to assign work to specific resources (e.g., I&C Maintenance Craft, Administrative Assistant, Scheduler, Planner, etc.)[4]
- Number of Resources Required – Provides the number of like resources that are needed/required to perform a task and is used to calculate Task Workload.
- Task Duration (Hours) – The number of hours the scheduler has planned to complete the task. Task Duration is used to calculate Task Workload.
- Task Workload (Resource Hours) – The total hours needed to complete a task line item; calculated as the product of [*Number of Resources Required]* and [*Task Duration]*.
- Annual Workload (Resource Hours) – The Annual Workload Reduction by accounting for the frequency assigned to the PMI. It is calculated as the product of [*No of PMIs with Task*], [*PMI Frequency*], [*No of Times Task is Performed per ST WO*], and [*Task Workload*].
- Workload Reduction (%) – The estimated percentage the Task Workload is expected to be reduced through the modernization effort. A 100% workload reduction indicates the task is completely eliminated. Lower percentages indicate some level of the task is expected to remain after the modernization is complete. For example, a digitally modernized system may greatly simplify a required ST, but the ST may still be required to fulfill the station's Tech Spec requirements.

4. The resource types identified in the WMS were inconsistent. The team developed a simplified list of resource types to consolidate like resources into a single category.

- Annual Workload Reduction – Indicates the total workload reduction expected as a result of the modernization, annualized based on the PMID frequency. It is calculated as the product of [*Annual Workload (Resource Hours)*] and [*Workload Reduction (%)*].

#### *3.1.6.2 Validation of PM Workload Reduction Data*

The team conducted a series of SME validation sessions to review the consolidated detail and summary data and make any adjustments necessary.

The validation sessions included SMEs from engineering, operations, maintenance, and work management. The objectives of the validation sessions were as follows:

- Provide an overview on how the data was collected and compiled.
- Provide an opportunity to make necessary adjustments to the data based on SME experience. For example, there might be wide discrepancies in the resources and time required on historical PM WOs tied to the same PMI. These discrepancies were reconciled during the validation sessions.
- Identify additional support tasks not identified on the WOs. (For example, the WO will identify tasks to perform the test, as well as key support activities from operations, but they generally do not identify time spent scheduling, coordinating, and supervising the work. These tasks were added in manually by the team with SME input.)

#### *3.1.6.3 Consolidation of PM Workload Reduction Data*

Consolidation of the PM Workload Reduction Data was performed in a similar manner to that illustrated in Figure A-3: Illustration of ST workload reduction summary worksheet above. The PM WO task level data can be summarized in a number of ways that is useful to the Project Team.

- Workload reductions can be grouped by FA, work group, or resource type depending on what the team is trying to achieve.
- Impacts to online workforce and outage workforce can be evaluated separately.
- Summary statistics can be developed and compared to other systems.

A template worksheet to consolidate and summarize PM workload reductions is provided in Appendix B—Sheet 2.5 of this research product.

### 3.1.7 Corrective Maintenance (CM) Workload Reduction Worksheet

#### *3.1.7.1 Synthesis of CM Workload Reduction Data*

To develop an estimate of expected CM workload reductions attributable to the proposed modernization, the team used a differing approach from that used for ST and PM workload reductions described above. As CM is unplanned work, work required in the future cannot be forecast. Rather, the historical expenditure of resource hours in aggregate was used as the basis to establish a trend that could be extrapolated as future workload reductions. The team utilized the In-Scope Equipment List provided by engineering to filter WMS data for corrective work orders over a 5-year span and synthesized the data onto a single worksheet as illustrated in Figure A-5, below. A template of this worksheet is provided in Appendix B—Sheet 2.3 of this research product.

| CM WO TASK LEVEL DATA | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| System Name | System No. | Equipment Number | Equipment Name | Device Type | WO No. | WO Description | System | WO Task No. | WO Task Title | Functional Area | Work Group | Resource Type | No. of Resource Req'd | Task Duration (Hrs | Task Workload (Resource-Hrs.) |
| ECCS - 4kV and EDGs | 92 | 162Z-11609 | 101-D12 SAFEGUARD XFMR BREAKER FEEDER BUS UNDERVOLTAGE AUX | Relay | 4587294 | 162Z-11609 NOT CHANGING STATE DURING ST-2-0923-322-1 | ECCS | 01 | 162Z-11609 (LMI3) BENCH CALIBRATE RELAY | MA | I&C | Craft | 1 | 4 | 4 |
| | | | | | | | ECCS | 02 | 162Z-11609 (LMI3) REPLACE UNDERVOLTAGE | MA | I&C | Craft | 1 | 4 | 4 |
| | | | | | | | ECCS | 03 | 162Z-11609 NOT CHANGING STATE DURING ST-2-0923-322-1 | MA | I&C | Craft | 1 | 4 | 4 |

Figure A-5: Illustration of CM labor workload reduction worksheet.

1. Corrective Maintenance Work Order Data –Sourced from the CM data file, this data provides information on CM activities performed in the field. The fields include:
   - System Description – A concatenated field from the in-scope system list that combines the name of the targeted safety system (e.g., RPS, ECCS) with the description of the engineering system (i.e., subsystem) tracked in the WMS.
   - System Number – The engineering system number provided in the WMS. This is linked to the targeted safety system via the in-scope system list.
   - Equipment Number – A unique identifier assigned by the engineer of record to equipment that is common to both engineering and design documentation and plant systems such as the WMS. This number was compared to the in-scope equipment list. Equipment not in scope were filtered out.
   - Equipment Name – Provides a brief description of the equipment requiring maintenance in the CM WO.
   - Corrective Maintenance Work Order Number – The unique identifier assigned to the WO in the WMS.
   - Corrective Maintenance Work Order Description – A brief description of the CM WO as provided by the WMS.
2. Corrective Maintenance Work Order Task Data – Sourced from the CM Data File and used to calculate expected workload reductions. The fields include:
   - System – The name of the targeted safety system targeted for modernization (e.g., RPS, ECCS, N4S) associated with the WO. This field is used to categorize the workload reductions when summing.
   - Work Order Task No – A sequential number assigned to task within a WO.
   - Work Order Task Title – Provides a brief description of the work to be performed in the task.
   - Task Workload (Resource Hours) – The product of [*Number of Resources Required*] and [*Task Duration*].
   - Functional Area – The area the assigned Resource Type belongs to. This data field is utilized to align the data with FA provided in Electric Power Research Institute (EPRI) BCAM model. However, an analyst may assign an FA that is aligned with the station's organization chart. The FA was utilized as a sorting function when summing data into various resource categories and allowed the Project Team to examine workload reductions across departments within the same

function. A list common Functional Areas as well as their corresponding acronyms, workgroups, and resource types is in Table A-4, in the prior section.

- Work Group – Assigned to the Resource Type (refer to Table A-4 above) by the analyst based on review of the station's organization chart. The Work Group was utilized as a sorting function when summing data into various resource categories and allowed the team to combine or segregate organizational impacts of workload reductions between groups.
- Resource Type –A description of the resource assigned to a WO Task. A simplified list for resource types was utilized to assign work to specific resources (e.g., I&C Maintenance Craft, Administrative Assistant, Scheduler, Planner, etc.)[5].
- Number of Resources Required – Provides the number of like resources that are needed/required to perform a task and is used to calculate Task Workload below.
- Task Duration (Hours) – The number of hours the scheduler has planned to complete the task. It is used to calculate Task Workload below.
- Task Workload (Resource Hours) – Indicates the total hours needed to complete a task line item and is calculated as the product of [*Number of Resources Required]* and [*Task Duration*].

#### *3.1.7.2 Validation of CM Workload Reduction Data*

The completed list of detailed tasks represents the overall expenditure of O&M field resources in terms of resource hours over a period of 5 years. All the CM work is assumed to be performed as online work.

The data is summarized onto a table into resource categories as the average annual resource hours expended on CM for the system. Key statistics were developed as follows:

- WOs per year
- WO tasks per year
- Average hours per WO
- Average hours per WO task.

These metrics were then used to estimate resource requirements to support the maintenance activities as provided in Table A-5, below:

Table A-5: Metrics utilized to estimate support workload for CM WOs.

| Support Resource Type | Estimate Basis |
|---|---|
| Craft Supervision | 1 hour per WO + 15 minutes per WO task |
| Clerical Support | 15 minutes per WO task |
| Scheduling and Coordination | 1 hour per WO |
| Planner | 2 hours per WO |
| Ops Support | 1 hour per WO |
| Ops Support SRO | 15 minutes per WO |

#### *3.1.7.3 Consolidation of CM Workload Reduction Data*

Once the data from the WMS was populated onto the CM Labor Detail worksheet, the team conducted a series of SME validation sessions to review the data and make any adjustments necessary.

5. The resource types identified in the WMS were inconsistent. The team developed a simplified list of resource types to consolidate like resources into a single category.

The validation sessions included SMEs from engineering, operations, maintenance, and work management. The objectives of the validation sessions were as follows:

- Provide an overview on how the data was collected and compiled.
- Examine CM WO and verify that the work described would not be performed if the system had undergone a modernization described in the project scope. Items identified in Section 2.3.1.2 (Labor Benefits: Preventive and CM Workload Reductions) of the base research report were leveraged as part of this effort.

A template worksheet to summarize CM workload reductions is provided in Appendix B—Sheet 2-6 of this research product.

### 3.1.8 Event Management and Corrective Action Program

The Project Team employed a methodology to look at historical incident rates in each system and estimate resource efforts required to close the incident under three typical scenarios:

1. Class A incident requiring a Root Cause Analysis (RCA)
2. Class B incident requiring an Apparent Cause Evaluation (ACE) or similar exercise
3. Class D incident requiring a Work Group Evaluation (WGE) or no formal investigation.

Class C is no longer used. To do this, the Project Team examined station procedures and broke down event management into three main processes:

1. Issue ID and screening
2. Event response, including subprocesses and station requirements
3. Implement corrective actions, including subprocesses, and regulatory requirements for:

   The Project Team, with support of SMEs, created an estimate of the cross-functional resources typically burdened under each scenario. An example of the worksheet is shown in Figure A-6 (see below) with sample data populated for a Class B scenario. A template for this worksheet has been provided in Appendix B—Sheet 2.7 of this research product.

**Work Estimate (typ. Per Event Type)**

| Work Breakdown | | Resource | | Class A (RCA) | | Class B (ACE) | | Class D (WGE) | |
|---|---|---|---|---|---|---|---|---|---|
| | Description (sample activities) | Function | Resource Type | No. of Persons | Duration (Hrs) | No. of Persons | Duration (Hrs) | No. of Persons | Duration (Hrs) |
| **1.0.** | **Issue ID and Screening** | | | **Hrs/Event** | **0** | **Hrs/Event** | **29.25** | **Hrs/Event** | **0** |
| | *Issue identification (Field)* | *MGMT* | *SOC* | | | 8 | 0.25 | | |
| | *Supervisor Review* | *OP* | *Shift Manager* | | | 1 | 2 | | |
| | *Creation of CAP* | *OP* | *Supervisor* | | | 1 | 2 | | |
| | *Shift Manager Review* | *OP* | *RO* | | | 1 | 2 | | |
| | *Issue Work Requests (immediate correctives)* | *OP* | *EO* | | | 1 | 3 | | |
| | *Document comments on IR* | *MA* | *Supervisor* | | | 1 | 0.25 | | |
| | *Station Ownership Committee Review/Screening* | *MA* | *Technician* | | | 2 | 4 | | |
| | *Update Corrective Actions and assignments on CAP* | *MA* | *Craft* | | | 2 | 1 | | |
| | | *FIN* | *Engineer* | | | 1 | 8 | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **2.0.** | **Event Reponse** | | | **Hrs/Event** | **0** | **Hrs/Event** | **148** | **Hrs/Event** | **0** |
| | *Establish Event Response Team (if req'd)* | *EN* | *Engineer* | | | 5 | 24 | | |
| | *Conduct Prompt Investigation* | *OP* | *Ops Services* | | | 1 | 12 | | |
| | | *MA* | *Planning* | | | 2 | 4 | | |
| | | *FIN* | *Craft* | | | 2 | 4 | | |
| | | | | | | | | | |
| **3.0.** | **Implement Corrective Actions** | | | **Hrs/Event** | **0** | **Hrs/Event** | **198** | **Hrs/Event** | **0** |
| | *MRC Reviews* | *MGMT* | *MRC* | | | 8 | 0.25 | | |
| | *Conduct Evaluation (RCA/CAPE/WGE)* | *EN* | *Engineer* | | | 1 | 112 | | |
| | *Prepare Evaluation Report* | *CA* | *Engineer* | | | 1 | 16 | | |
| | *Review Evaluation Reports* | *LS* | *Engineer* | | | 1 | 40 | | |
| | *Enter Assignments in CAP* | *OP* | *Writer* | | | 1 | 16 | | |
| | *Manage Actions* | *RM* | *Writer* | | | 1 | 8 | | |
| | *Complete Actions - Field Maint* | *MA* | *Planning* | | | 1 | 4 | | |
| | *Complete Actions - Admin/Regulatory Reports* | | | | | | | | |
| | *Complete Actions - Notifications* | | | | | | | | |
| | *Document Operating Experience* | | | | | | | | |
| | *Conduct Effectiveness Review* | | | | | | | | |
| | *Close out Corrective Actions* | | | | | | | | |
| | | | | **Total Hrs** | **0** | **Total Hrs** | **375.25** | **Total Hrs** | **0** |

Figure A-6: Example labor workload estimate per incident report with sample data.

Once the typical or expected administrative burden for each scenario was estimated, the Project Team examined the number of Incident Reports logged in the CAP. Incident Reports for a 5-year period for in-scope systems were tabulated and classified into each of the three scenarios. Each incident report was examined to determine if the incident was caused by a failure of a safety system component. Average annual incidents were then calculated and tabulated. The Annual Workload Reduction was then calculated from these figures and entered the worksheet illustrated in Figure A-7 (see below) with sample data of the Class B scenario. A template of this worksheet is provided in Appendix B—Sheet 2.7 of this research product.

**No. of Events 2014-Present (Ref. "IR Scope Determination Workbook")**

| Event Classification | Number of Events (2014 to Present) | | | | |
|---|---|---|---|---|---|
| | System 1 | System 2 | System 3 | System 4 | Common |
| Class A (RCA) | | | | | |
| Class B (ACE) | 1.0 | - | 2.0 | 1.0 | - |
| Class D (WGE or no formal investigation) | | | | | |

**No. of Events per Year**

| Event Classification | Number of Events per Year | | | | |
|---|---|---|---|---|---|
| | System 1 | System 2 | System 3 | System 4 | Common |
| Class A (RCA) | | | | | |
| Class B (CAPE or EACE) | 0.2 | - | 0.3 | 0.2 | - |
| Class D (WGE or no formal investigation) | | | | | |

**Event Management and CAP Annual Hours**

| Event Classification | Workload (Hrs./Yr.) | | | | | Total |
|---|---|---|---|---|---|---|
| | System 1 | System 2 | System 3 | System 4 | Common | |
| Class A (RCA) | | | | | | |
| Class B (CAPE or EACE) | 65.3 | - | 130.5 | 65.3 | - | 261 |
| Class D (WGE or no formal investigation) | | | | | | |
| **TOTAL** | **65** | **-** | **131** | **65** | **-** | **261** |

Figure A-7: Summary labor workload reduction for event management and CAP activities.

## 3.1.9 Other Functional Areas Evaluated

### *3.1.9.1 Engineering*

The Project Team conducted interviews with System Engineers to estimate the level of support that would no longer be necessary with a modern digital system. System Engineers currently spend a significant portion of their time troubleshooting system faults and failed system components and supporting procurement in sourcing and refurbishing components that are approaching obsolescence (primarily in support of the Anticipated Transient Without Scram Mitigation System). It was postulated that improved reliability of modern solid-state components would eliminate much of these efforts. The Project Team applied an estimate for System Engineering workload reduction as approximately 8–10% of a System Engineer's time and included this workload in the aggregated workload summary described in Section 3.2, below.

### *3.1.9.2 Supply Chain and Warehousing*

The Project Team conducted interviews with Supply Chain SMEs to determine if quantifiable benefits could be credited to the project. Through discovery, it was determined that procurement and warehousing functions are corporate support functions provided to the station and not part of the station's budget. More specifically, it was not likely that the implementation of the modernization would change the current level of support provided to the plant and therefore the team was unable to credit any quantifiable benefit to this function.

### *3.1.9.3 Training*

The Project Team conducted interviews with O&M training SMEs to determine if the proposed modernization project would have beneficial impacts on these programs. It was determined that there would be little, if any, impact on either these programs. As a result, benefits related to workload reduction in training programs were not investigated further.

## 3.2 Aggregation of Labor Benefits

Once estimates of workload reductions have been assessed for the plant's functional areas in the form of annual resource hours, the summary results may be presented on a single table to support an analysis of how to best harvest these reductions. Figure A-8, below, provides an example of such a summary where the data is organized into a matrix of resources and work activity.

Summarizing the workload reductions in this way allows the Project Team to sum reductions in different ways and demonstrate how these reductions can be actualized as budget reductions at the station. Benefits that can be translated to staffing reductions are regarded as harvestable labor benefits.

| Labor Division | | | ONLINE LABOR WORKLOAD REDUCTION | | | | | | | | | | | | | | | | | | TOTAL ONLINE WORKLOAD REDUCTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | System 1 | | | | System 2 | | | | System 3 | | | | System 4 | | | | Common | | |
| Functional Area | Work Group | Resource Type | ST Labor Workload | PM Labor Workload | CM Labor Workload | Other Support | ST Labor Workload | PM Labor Workload | CM Labor Workload | Other Support | ST Labor Workload | PM Labor Workload | CM Labor Workload | Other Support | ST Labor Workload | PM Labor Workload | CM Labor Workload | Other Support | Syst 042 | Rounds | |
| MA | I&C | Supervisor | | | | | | | | | | | | | | | | | | | - |
| | | Craft | | | | | | | | | | | | | | | | | | | - |
| | | Clerical | | | | | | | | | | | | | | | | | | | - |
| | Electrical | Supervisor | | | | | | | | | | | | | | | | | | | - |
| | | Craft | | | | | | | | | | | | | | | | | | | - |
| | | Clerical | | | | | | | | | | | | | | | | | | | - |
| | Mechanical | Craft | | | | | | | | | | | | | | | | | | | - |
| | Support | Craft | | | | | | | | | | | | | | | | | | | - |
| | CMO | Technician | | | | | | | | | | | | | | | | | | | - |
| | Reactor Services | Technician | | | | | | | | | | | | | | | | | | | - |
| | Maint Prep | Supervisor | 26 | - | - | - | - | - | - | - | 76 | - | - | - | 86 | - | - | - | - | 183 | 371 |
| | | Scheduler | 105 | - | 1 | - | - | - | 7 | - | 329 | - | 5 | - | 372 | - | 9 | - | 6 | - | 835 |
| | | Clerical | 22 | - | - | - | - | - | - | - | 76 | - | - | - | 86 | - | - | - | - | 219 | 403 |
| WM | Maint Prep | Planner | 89 | - | 3 | - | - | - | 21 | - | 329 | - | 12 | - | 372 | - | 19 | - | 12 | - | 858 |
| | Outage Mgmt | Scheduler | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | Planner | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| OP | Shift Ops | SRO | 14 | - | 0 | - | - | - | 2 | - | 76 | - | 1 | - | 94 | - | 2 | - | 2 | 511 | 702 |
| | | RO | 129 | - | 1 | - | - | - | 13 | - | 108 | - | 5 | - | 132 | - | 14 | - | 7 | 365 | 775 |
| | | EO | 60 | - | - | - | - | - | 3 | - | 64 | - | - | - | 20 | - | - | - | 4 | 2,920 | 3,071 |
| | Support Services | Scheduler | | | | | | | | | | | | | | | | | | | - |
| | | Planner | | | | | | | | | | | | | | | | | | | - |
| | | Clerical | | | | | | | | | | | | | | | | | | | - |
| | Reactor Eng | Engineer | | | | | | | | | | | | | | | | | | | - |
| EN | Syst Eng | Supervisor | | | | | | | | | | | | | | | | | | | - |
| | | Engineer | | | | | | | | | | | | | | | | | | | - |
| RP | Support | Technician | | | | | | | | | | | | | | | | | | | - |
| CY | Chemistry | Technician | | | | | | | | | | | | | | | | | | | - |
| CA | CAP | Various | | | | | | | | | | | | | | | | | | | - |
| TR | Ops | Various | | | | | | | | | | | | | | | | | | | - |
| | Maint | Various | | | | | | | | | | | | | | | | | | | - |
| IT | IT | Analyst | | | | | | | | | | | | | | | | | | | - |
| TOTAL Number of Annual Hours: | | | 445 | 0 | 6 | 0 | 0 | 0 | 46 | 0 | 1,059 | 0 | 24 | 0 | 1,163 | 0 | 45 | 0 | 31 | 4,198 | |
| | | | | | | 451 | | | | 46 | | | | 1,082 | | | | 1,208 | | 4,229 | 7,015 |
| | | | | | | | | | | | | | | | | | | | | | OK |

| Labor Division | | | OUTAGE LABOR WORKLOAD REDUCTION | | | | | | | | TOTAL OUTAGE WORKLOAD REDCUTION | TOTAL WORKLOAD REDUCTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | System 1 | | System 2 | | System 3 | | System 4 | | | |
| Functional Area | Work Group | Resource Type | ST Labor Workload | PM Labor Workload | ST Labor Workload | PM Labor Workload | ST Labor Workload | PM Labor Workload | ST Labor Workload | PM Labor Workload | | |
| MA | I&C | Supervisor | | | | | | | | | - | - |
| | | Craft | | | | | | | | | - | - |
| | | Clerical | | | | | | | | | - | - |
| | Electrical | Supervisor | | | | | | | | | - | - |
| | | Craft | | | | | | | | | - | - |
| | | Clerical | | | | | | | | | - | - |
| | Mechanical | Craft | | | | | | | | | - | - |
| | Support | Craft | | | | | | | | | - | - |
| | CMO | Technician | | | | | | | | | - | - |
| | Reactor Services | Technician | | | | | | | | | - | - |
| | Maint Prep | Supervisor | 1 | - | - | - | 2 | - | 1 | - | 4 | 375 |
| | | Scheduler | - | 10 | - | 3 | - | 5 | - | 1 | 18 | 854 |
| | | Clerical | 1 | - | - | - | 2 | - | 1 | - | 4 | 407 |
| WM | Maint Prep | Planner | - | 18 | - | - | - | 17 | - | 10 | 45 | 903 |
| | Outage Mgmt | Scheduler | 41 | - | - | - | 48 | - | 69 | - | 158 | 158 |
| | | Planner | 29 | - | - | - | 31 | - | 48 | - | 107 | 107 |
| OP | Shift Ops | SRO | 1 | 5 | - | - | 2 | 8 | 1 | 1 | 18 | 720 |
| | | RO | 6 | 11 | - | - | 47 | 35 | 79 | 8 | 187 | 962 |
| | | EO | 32 | - | - | - | 58 | 43 | 58 | 3 | 195 | 3,266 |
| | Support Services | Scheduler | | | | | | | | | - | - |
| | | Planner | | | | | | | | | - | - |
| | | Clerical | | | | | | | | | - | - |
| | Reactor Eng | Engineer | | | | | | | | | - | - |
| EN | Syst Eng | Supervisor | | | | | | | | | - | - |
| | | Engineer | | | | | | | | | - | - |
| RP | Support | Technician | | | | | | | | | - | - |
| CY | Chemistry | Technician | | | | | | | | | - | - |
| CA | CAP | Various | | | | | | | | | - | - |
| TR | Ops | Various | | | | | | | | | - | - |
| | Maint | Various | | | | | | | | | - | - |
| IT | IT | Analyst | | | | | | | | | - | - |
| TOTAL Number of Annual Hours: | | | 111 | 44 | 0 | 3 | 189 | 108 | 257 | 23 | | |
| | | | | 155 | | 3 | | 298 | | 280 | 736 | 7,750 |
| | | | | | | | | | | | OK | OK |

Figure A-8: Illustration of annual labor workload reduction summary sheet.

In the determination of harvestable labor benefits for proposed modernization project, the Project Team identified harvestable Full-Time Equivalents (FTE) in the following resource types:

- Maintenance – I&C craft
- Maintenance prep and work management
- Operations – Equipment Operators (or equivalent crew resources).

A template of this summary sheet is provided in Appendix B—Sheet 2.10 of this research product.

### 3.2.1 Determination of Harvestable FTEs

Harvestability is defined as the actual reduction in required workload in units of FTEs notwithstanding regulatory staffing requirements. More specifically, estimated workload reductions must be at least equal or greater than 1 FTE in resource hours for a particular resource function to be counted as harvestable. To determine harvestability, the Project Team summed up the total online workload reductions by resource types and determined if the workload reduction was great enough to affect an organization in terms of the number of FTEs.

A worksheet has been provided in Appendix B—Sheet 2.11 with example data to assist the analyst in determining the number of harvestable resources. This is also shown in Figure A-9, below. In Part I of the worksheet, the analyst determines the fractional FTE values derived from the summary workload reductions for each resource type. In Part II of the worksheet, the analyst works with the Project Team to see if resources may be combined or workload transitioned to other groups to enable organizational reductions.

**PART I. FRACTIONAL FTE**

| Labor Division | | | Exclude Outage Workload? (Yes/No) | Workload Reduction (Hrs.) | Effective Hrs. per FTE | Potential Harvestable Resource? | Fractional Harvestable FTE | Comments |
|---|---|---|---|---|---|---|---|---|
| Functional Area | Work Group | Resource Type | | | | | | |
| MA | I&C | Supervisor | Yes | - | | | | |
| | | Craft | Yes | - | | | | |
| | | Clerical | Yes | - | | | | |
| | Electrical | Supervisor | Yes | - | | | | |
| | | Craft | Yes | - | | | | |
| | | Clerical | Yes | - | | | | |
| | Mechanical | Craft | Yes | - | | | | |
| | Support | Craft | Yes | - | | | | |
| | CMO | Technician | Yes | - | | | | |
| | Reactor Services | Technician | No | - | | | | |
| | Maint Prep | Supervisor | No | 375 | 1,700 | No | 0.220 | |
| | | Scheduler | No | 854 | 1,700 | No | 0.502 | Combine Scheduler/Planner and redistribute work |
| | | Clerical | No | 407 | 2,000 | No | 0.204 | |
| WM | Maint Prep | Planner | No | 903 | 1,700 | No | 0.531 | |
| | Outage Mgmt | Scheduler | No | 158 | 1,700 | No | 0.093 | |
| | | Planner | No | 107 | 1,700 | No | 0.063 | |
| OP | Shift Ops | SRO | No | 720 | 1,400 | No | 0.514 | |
| | | RO | No | 962 | 1,400 | No | 0.687 | |
| | | EO | No | 3,266 | 1,400 | Yes | 2.333 | Reassign Chemistry Operator tasks to Ops |
| | Support | Scheduler | No | - | | | | |
| | Services | Planner | No | - | | | | |
| | | Clerical | No | - | | | | |
| | Reactor Eng | Engineer | No | - | | | | |
| EN | Syst Eng | Supervisor | No | - | | | | |
| | | Engineer | No | - | | | | |
| RP | Support | Technician | No | - | | | | |
| CY | Chemistry | Technician | No | - | | | | |
| CA | CAP | Various | No | - | | | | |
| TR | Ops | Various | No | - | | | | |
| | Maint | Various | No | - | | | | |
| IT | MI | Analyst | No | - | | | | |

**PART II. CONSOLIDATED RESOURCES AND POTENTIAL FTE REDUCTIONS**

| Resource Description | | Total Workload Reduction (Hrs.) | Effective Hrs. per FTE | Potential Harvestable Resource? | Potential Harvestable FTE (Whole) | Comments |
|---|---|---|---|---|---|---|
| Chemistry | | 4,227 | 1,400 | Yes | 3.0 | |
| Scheduler/Planner (Maint Prep & Outage Mgt) | | 1,757 | 1,700 | Yes | 1.0 | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| TOTAL FTE | | | | | 4.0 | |

Figure A-9: Illustration of FTE harvestability worksheet with sample data.

The following examples illustrate how the concept of harvestability can be applied.

***Example 1.***

> *A benefits analysis has been completed on a station initiative to outsource operation of a water dosing system to an external contractor. The project indicates that the station may expect an annual reduction of 250 hours of mechanical maintenance labor and 1,050 hours in chemistry labor. The FTE equivalent is 1,400 hours for a mechanical craft person and 1,600 hours for a chemistry technician. This workload reduction is therefore not harvestable as the workload reductions do not meet the threshold of one FTE for either resource type.*

In some cases, like resources from different work groups can be combined to achieve harvestability.

***Example 2.***

> *A station is considering implementing a new computer-based WMS which features paperless WOs. A benefits analysis has been completed that indicates workload related to clerical support in various work groups will be reduced as follows:*
>
> - *Mechanical Maintenance – 600 hours*
> - *Electrical Maintenance – 1,350 hours*
> - *Instrument Maintenance – 1,550 hours*
> - *Maintenance Planning – 900 hours*

-----------------------------------------------------

*Total Clerical Workload Reduction – 4,400 hours*

> *The FTE equivalent of a clerical worker is 1,800 hours. Individually, the workload reductions listed above are not harvestable form any one work group. The team then discussed the project with department leads and determined that clerical resources could be shared between work groups in a way to support harvestability of two FTEs.*

Regulatory staffing requirements are an obstacle but can be overcome in certain situations:

***Example 3.***

> *A modernization of plant operations is being proposed for a station which is expected to reduce the workload of equipment operators by the equivalent of three FTEs. The station's operations staffing currently is at the minimum allowed per shift under its current operating license. However, the workload reductions allow plant operations to take on some field tasks currently performed by Chemistry. After analysis of the Chemistry workload that could be transferred to operations, the team recognized that at least two FTEs could be harvested from Chemistry as a result of the modernization.*

### 3.2.2 Treatment of Outage Workload Reductions

Early in discovery, the team recognized that a sizable portion of the workload reductions identified were executed during outages. Outages are periods where the unit is taken off-line to perform maintenance activities that cannot otherwise be executed while the plant is in operation. Outages are typically 3 to 4 weeks in duration and must be supported with external labor to complete maintenance activities within this timeframe. For this reason, it would be imprudent to identify staffing reductions based on outage workload reductions. Rather, the team credited outage workload reductions as outage contract labor savings and only utilized workload reductions identified as online work towards identifying harvestable FTEs.

## 3.3 Other Benefits Attributable to Workload Reductions

### 3.3.1 Overtime Reductions

The Project Team investigated if unharvested workload reductions could be credited towards overtime reductions as illustrated in Figure A-10 (see below). A template of this worksheet has been provided in Appendix B—Sheet 2.8 of this research product.

Where unharvestable resources were eligible for overtime, the workload reductions were quantified as a function of their estimated rate of pay.

| Labor Division | | | Total Workload Reduction (Hrs) | Potential Harvestable Resource? | Labor Rate ($/Hr) | OT Multiplier (x Labor Rate) | Overtime Cost |
|---|---|---|---|---|---|---|---|
| Functional Area | Work Group | Resource Type | | | | | |
| MA | I&C | Supervisor | 450 | No | | 1.25 | 0 |
| | | Clerical | 160 | No | | 1.50 | 0 |
| | Electrical | Supervisor | 20 | No | | 1.25 | 0 |
| | | Craft | 160 | No | | 1.50 | 0 |
| | | Clerical | 10 | No | | 1.50 | 0 |
| | Mechanical | Craft | 5 | No | | 1.50 | 0 |
| | Support | Craft | 105 | No | | 1.50 | 0 |
| | CMO | Technician | 100 | No | | 1.50 | 0 |
| WM | Maint Prep | Planner | 900 | Yes | | 1.50 | n/a |
| | Outage Mgmt | Scheduler | 200 | No | | 1.50 | 0 |
| | | Planner | 120 | No | | 1.50 | 0 |
| OP | Support | Scheduler | 10 | No | | 1.50 | 0 |
| | Services | Planner | 15 | No | | 1.50 | 0 |
| | | Clerical | 60 | No | | 1.50 | 0 |
| **Total** | | | | | | | **$0** |

Figure A-10: Illustration of overtime labor reduction worksheet.

### 3.3.2 Treatment of Remainder Unharvestable Benefits

Any remaining unharvested labor benefits were recorded as available for other uses but were not quantified as monetary benefits for the purposes of a business case. These benefits are identified and made available for management discretion, possibly to achieve other strategic objectives. Examples of strategic objectives where unharvested workload reductions might be used:

- Reduction of backlog (i.e., maintenance, training)
- Improved situational awareness (operations)
- Participation in performance improvement efforts
- Potential to combine savings with other initiatives.

## 3.4 Contract Services

The Project Team investigated any contract services that could be eliminated as a result of the proposed project. The team did not identify contract services in addition to contractor savings identified as part of direct labor workload reductions. A simple worksheet has been provided in Appendix B—Sheet 2.8 of this research product to collect data related to contract services.

## 3.5 Challenge Sessions – Labor Benefits

Upon initially estimating the labor benefits of the project, the Project Team conducted a series of challenge sessions with station SMEs and representatives of the owner's Project Management and Finance Organizations. In the challenge sessions, the Project Team presented the approach and methodology used to collect, synthesize, and analyze the data to estimate the labor benefits. The attendees were encouraged to challenge any of the data, assumptions, or results presented during the session. The Project Team offered clarifications and any feedback was incorporated into the BCA model.

## 3.6 Lessons Learned

Table A-6: Lessons Learned – Estimation of labor benefits.

| Number | Lesson Learned |
|---|---|
| 3-1 | The Project Team worked closely with the station's IT department to create custom reports from the WMS. |
| 3-2 | The resource types identified in the WMS were inconsistent. The team developed a simplified list of resource types to consolidate workload into like resources. |
| 3-3 | Use of SMEs is critical in verifying workload estimates made from WMS data and identifying support resources not identified in the WO (e.g., Planner, Scheduler, Supervisor, Clerical). |
| 3-4 | Due to the diverse nature of event management and corrective action responses to incidents, the workload estimated for this category is not attributable to the resolution of resource type. As such, workload associated with this category is quantifiable, but not considered harvestable workload. |
| 3-5 | The analysis does not credit outage related workload reductions towards potential harvestable FTE reductions. Rather, direct labor workload reductions were credited as reductions in contracted I&C outage support labor. |

# 4. Estimation of Equipment and Materials Benefits

This section describes an approach to estimating equipment and material benefits utilized to produce the BCA for this research product. It outlines detailed methods and calculations employed to perform this BCA. Sample tools and templates are offered in conjunction with this description and are provided in Appendix B.

## 4.1 Establishing Materials List

The Project Team utilized a similar approach to estimate reductions in cost of equipment and materials as was done for labor. The team, with support from the station's IT department, created a custom report to download historical records of materials requested by maintenance from the station's WMS.

Reports were run for each of the in-scope systems identified and produced data files which were provided to the Project Team in MS Excel format. Like the reports generated for labor, these files contained tens of thousands of records dating back over 30 years. The key fields utilized in these reports are:

- System Code – Provided to IT to run the report. A report was run for each of the in-scope systems identified as part of an engineering study.
- Unit Number – Describes to which of the station's generating units the WO was assigned. The team analyzed data for one of the station's two units with the assumption that the benefits would be nearly identical for both units. This cut the amount of data to analyze by half.

- Work Order Type – The WMS maintained several WO types. The team focused on WOs that were identified as PM (including STs) and CM.
- Work Order Number – A unique identifier assigned to the WO.
- Work Order Description – Provides a brief description of the WO, sometimes indicating the equipment being maintained.
- Job Status (Open/Closed) – The team only examined WOs that were closed. Open WOs were filtered out.
- Work Order Status Date – Indicates the date the work order status was last updated. The team utilized this field to limit the data analyzed to the last 10 years[6].
- Equipment Number – A unique identifier of the equipment item assigned by engineering and design. This number was compared to the in-scope equipment list. Equipment not in scope were filtered out.
- Equipment Name – Provides a brief description of the equipment.
- Equipment Type – Provides a code that broadly identifies an equipment category (i.e., Electrical, Instrumentation, Piping, etc.). The team utilized this field to filter out mechanical, process and piping equipment, and focused solely on work orders related to instrument and electrical equipment.
- Catalog ID – A unique number assigned to any purchased item stocked in the warehouse.
- Catalog Description – Provides a brief description of a catalog item.
- Quantity Material Requested – The number of units of material required to execute the WO.
- Unit of Issue – Describes the unit of measure of a catalog item.
- Estimated Cost – Estimated value of a catalog item (multiplied by quantity requested) at the time material is requested as calculated by an algorithm in the WMS. It does not reflect actual purchase price of materials.

These reports were then filtered to include materials for equipment identified on the in-scope equipment list and consolidated into a single database.

The data was then pivoted to produce a Materials List that was sortable by Catalog ID and broken down by system and manually scrubbed to eliminate consumables items (e.g., fuses, hardware, grease, wiring, and tubing) that were likely commonly used throughout the station.

## 4.2 Materials Estimate Worksheet

Once the Materials List was established, the process of estimating system benefits can be performed by utilizing a Materials Estimate Worksheet as illustrated in Figure A-11 below and synthesizing information from the Materials List and the Owner's procurement system. The analyst should populate the input worksheet fields in the Materials Estimate Worksheet for each primary system targeted for modernization. Though the Materials List contains data from the last 10 years, the analyst should populate the worksheet with inputs from the most recent five years to ensure relevant averages and growth calculations. A template of this worksheet is provided in Appendix B—Sheet 3.1 of this research product.

6. The analyst may choose to extend this time horizon to 15 years.

**System 1 Materials Estimate Worksheet**

| Catalog Item Description | CATID No. | Unit Price | Unit Price Year | Allocation to System | Current Unit Price | Qty in Inventory | Current Value of Inventory | Qty Purchased (5-Year) | Estimated Annual Expenditure | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Agastat Relay | 0011411708 | $ 445 | 2017 | 100% | $ 530 | 56 | $ 29,693 | 119 | $ 10,974 | |
| Contactor | 0011498631 | $ 579 | 2017 | 30% | $ 689 | 150 | $ 31,019 | 478 | $ 17,191 | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | Current Year: | 2020 | | | | Total: | $ 60,713 | Total: | $ 28,165 | |
| | Weighted Average Component Unit Cost CAGR: | 6.0% | | | | | | | | |

Figure A-11: Illustration of material benefits worksheet for system.

#### *4.2.1.1 Fields Sourced from Materials List*

- Catalog Item Description – Provides a brief description of the catalog item.
- Catalog Identification (CATID) Number – A unique number assigned to any purchased item stocked in the warehouse.

#### *4.2.1.2 Fields Sourced from Mining Owner's Procurement System*

- Unit Price – Selected from the procurement system as the most recent price paid for a catalog item.
- Unit Price Year – The year of the most recent purchase date of a catalog item.
- Quantity in Inventory – The current number of units available of a catalog item.
- Quantity Purchased (5-Year) – The sum of all purchases of a catalog item for the most recent 5-year period.

#### *4.2.1.3 Fields Input by the Project Team*

- Weighted Average Component Unit Cost Compound Annual Growth Rate (CAGR) – A product of a separate analysis of historical purchase records for a sample of catalog items belonging to a system (refer to Section 4.4.1 of this Appendix).
- Current Year – Current Year represents the year in which the benefits analysis is conducted. It is also equivalent of "year zero" of a present value analysis.
- Allocation to System – A percentage estimated by the Project Team (and validated by SMEs) where the CATID is known to be utilized in multiple systems. For example, the subsystems that make up the ECCS and N4S share several common components. The usage of these components was allocated to the primary system by the examining of the number of WO records where the component was called out.
- Miscellaneous, Sundry, and Consumable Items – Estimated as a percentage of annual purchased materials to account for minor items not accounted for in the Materials List.
- Estimated Annual Cost of Materials – The sum of [Total Annual Expenditure of Materials] and estimated value of [Miscellaneous, Sundry, and Consumable Items] for a given system.

#### *4.2.1.4 Fields Calculated by the Worksheet*

- Current Year Unit Price – Represents the last-known purchase price expressed in current year dollars and is calculated as:

- $Current\ Year\ Unit\ Price\ = Unit\ Price\ x\ (1 + Esc.Rate)^{(Current\ Year - Unit\ Price\ Year)}$
- Current Value of Inventory – The product of [Current Year Unit Price], [Quantity in Inventory] and [Allocation to System]
- Estimated Annual Expenditure – Calculated as the annual average of the 5-year expenditure
- Total Value of Inventory – The sum of Value of Inventory of catalog items allocated to a system
- Total Annual Expenditure – The sum of annual expenditures of components allocated to a system.

## 4.3 Materials Summary Table

A table was developed to assist in summarizing the Estimated Total Annual Cost of Materials and illustrated in Figure A-12 (see below). A template for this table is provided in Appendix B—Sheet 3.1 of this research product.

**System 1 Materials Estimate Summary Table**

| | | | | |
|---|---|---|---|---|
| **Estimated Annual Cost of Materials** | **$** | **30,418** | | |
| Total Estimated Annual Expenditure of Mat'ls | $ | 28,165 | | |
| Misc., Sundry and Consumable Items | $ | 2,253 | 8% | of Annual Expenditure |
| | | | | |
| **Estimated Carrying Cost of Materials** | **$** | **6,071** | | |
| Annual Depreciation | | | 20 | years (not applicable) |
| Supply Chain and Warehousing Charges | | | 0.0% | (not applicable) |
| Capital Carrying Cost of Inventory | $ | 6,071 | 10.0% | Cost of Capital |
| Property Taxes | | | 0.0% | (not applicable) |
| Insurance | | | 0.0% | (not applicable) |
| | | | | |
| **Estimated Total Annual Cost Materials** | **$** | **36,489** | | |

Figure A-12: Illustration of materials estimate summary table.

### 4.3.1 Estimated Annual Cost of Materials

The Estimated Annual Cost of Materials consists of two components. The first component, Total Estimated Annual Expenditure of Materials, is taken directly from the Materials Estimate Worksheet described in Section 4.2 above. The second component, Miscellaneous, Sundry, and Consumable Items is derived by factoring the Estimated Annual Cost of Materials. This component is an “add-back” of items that were excluded from the data when producing the Materials List described in Section 4.1 of this Appendix. The factor used (shown as 8% in Figure A-12 above) was estimated by the Project Team and validated by SMEs.

### 4.3.2 Estimating the Carrying Cost of Inventory

The Project Team investigated benefits associated with reduced inventory of system components. For each Materials Estimate Worksheet, the following was estimated by the Project Team (if applicable):

- Cost of Capital – The Owner’s expected IRR on investments
- Capital Carrying Cost – Represents the opportunity cost of maintaining assets in inventory that might otherwise be invested elsewhere. It is calculated as the Value of Inventory multiplied by the Owner’s cost of capital.
- Supply Chain and Warehousing Charges – If applicable, these are the estimated costs for procurement and warehousing services borne by the station.

- Annual Depreciation **–** If applicable, this is the write down of the value of inventory. This cost maybe dependent on Owner's treatment of assets in inventory.
- Property Taxes – If applicable, these are costs borne by the Owner based Value of Inventory and regulations by the local taxing authority.
- Insurance – If applicable, these are costs borne by the Owner to insure the value of assets in inventory from loss and/or damage.

## 4.4 Estimating Escalation Rate of Component Unit Costs and System Expenditures

Early interviews conducted with Station System Engineering and Procurement provided the Project Team with anecdotal evidence indicating the price of components has risen sharply in recent, years particularly with certain systems (refer to Appendix C—A Case Study in Component Obsolescence). Understanding the rate of escalation of materials is important as it can significantly impact the valuation of inventory and the NPV and IRR of the project when calculating project financial metrics. The Project Team investigated and conducted an analysis of material escalation to both validate the claims made by station SMEs and to establish reasonably accurate escalation rates for the project.

Escalation of material expenditures over the lifecycle of equipment are primarily due to two factors:

1. Inflation – Inflation of both labor and commodity materials are typically factored into estimates at rates of 3–5% material costs.
2. Obsolescence – Escalation of cost to maintain legacy equipment that is approaching end of life:
    i. Deterioration of reliability of aging components in the field can lead to more frequent replacements and drives increases in total annual expenditures.
    ii. As vendors modernize their products and demand for replacement components declines, legacy components become increasingly more expensive to produce which drives unit costs of manufacturing upwards (i.e., loss of economy of scale).
    iii. Market power to price components is shifted to the supplier, particularly if the supplier is the sole source of the component.

The Project Team conducted two types of analysis to establish escalation rates used in the project.

### 4.4.1 Escalation of Material Expenditures

Escalation of material expenditures examines historical material expenditures over a period of 10 to 15 years to establish a trend (i.e., CAGR) that can be extrapolated to model expected expenditures in future years. The advantage of this analysis is that it fully accounts for all three factors of inflation, reliability, and obsolescence described earlier, and is suitable to calculate project NPV and IRR. In addition, if the escalation of material expenditures is adjusted for inflation, the project benefit attributed to obsolescence can be presented as an opportunity expressed in present dollars.

A Project Team utilized a worksheet illustrated with sample data in Figure A-13 (see below) to calculate the CAGR for each system. A template of this worksheet is provided in Appendix B—Sheet 3.2 of this research product.

### 4.4.2 Escalation of Component Unit Costs

**System 1**

| Year | Total Material Expenditure | 3-Year Moving Average Material Expenditure |
|---|---|---|
| 2002 | $9,489 | |
| 2003 | $58,850 | |
| 2004 | $0 | $22,780 |
| 2005 | $42,709 | $33,853 |
| 2006 | $70,668 | $37,792 |
| 2007 | $16,250 | $43,209 |
| 2008 | $71,871 | $52,930 |
| 2009 | $57,762 | $48,628 |
| 2010 | $39,850 | $56,494 |
| 2011 | $90,700 | $62,771 |
| 2012 | $56,455 | $62,335 |
| 2013 | $236,631 | $127,929 |
| 2014 | $149,896 | $147,661 |
| 2015 | $157,200 | $181,242 |
| 2016 | $92,662 | $133,253 |
| 2017 | $185,838 | $145,233 |
| 2018 | $246,937 | $175,146 |
| 2019 | $483,832 | $305,536 |

| Mat'l 3-Year Ave. Compound Annual Growth Rate | | |
|---|---|---|
| | Year | Expenditure |
| Start | 2004 | $22,780 |
| End | 2019 | $305,536 |
| | **CAGR** | **19%** |

Figure A-13: Illustration of escalation of material expenditures worksheet.

Escalation of component unit costs examines historical unit prices of a sample set of representative components over a period of 10 to 15 years to establish a CAGR of unit price. A weighted average calculation is utilized to obtain this. This escalation rate is useful in establishing the current value and carrying cost of inventory.

The Project Team utilized a worksheet as illustrated in Figure A-14 (see below) to collect and analyze data for the purpose of establishing the rate of escalation of component unit costs. In Part II of the worksheet, sample components (i.e., Catalog Items) are researched and a CAGR is calculated for each sample. Enough samples should be selected to account for a sizable portion of total expenditures. The CAGR for each sample is entered into Part I and the weighted average CAGR is calculated using the price and quantity purchase over the last five-year period as the weight. A template of this worksheet is provided in Appendix B—Sheet 3.3 of this research product.

**PART I. Weighted Average Component Unit Cost Escalation Worksheet (1 Sheet per System)**

| Sample No. | Cat ID | Component Description | Latest Price | 5-Yr Qty Purchased | Weight (Price x Qty) | CAGR |
|---|---|---|---|---|---|---|
| 1 | 11437163 | Power Supply | $ 7,500.00 | 2 | 15,000 | 13.8% |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
| | | | | Weighted Average CAGR | | 13.8% |

**Part II. Sample Data for Standard Escalation Rate Analysis:**

**Sample 1**

| Component Name | CAT_ID | Qty Used Since 2003 |
|---|---|---|
| SUPPLY, POWER, 115 | 11437163 | |
| VAC/60 HZ INPUT, | | |

**Purchasing Data**

| | PO | PO Date | Unit Price | Qty Purchased | Notes (e.g., Cat ID) |
|---|---|---|---|---|---|
| 1 | 523841 | 2/8/2019 | $7,500.00 | 1 | |
| 2 | 90089992 | 11/1/2017 | $5,000.00 | 1 | |
| 3 | 90060100 | 4/22/2013 | $3,595.00 | 1 | |
| 4 | 90056836 | 11/12/2012 | $3,270.00 | 1 | |
| 5 | 90033651 | 9/25/2009 | $1,800.00 | 1 | |
| 6 | 90033651 | 9/25/2009 | $1,800.00 | 1 | |
| 7 | 90013785 | 3/13/2005 | $1,221.00 | 1 | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |

| Year | Price |
|---|---|
| 2005 | $1,221.00 |
| 2019 | $7,500.00 |
| **CAGR** | **13.8%** |

Figure A-14: Illustration of component unit cost escalation rate worksheet.

## 4.5 Challenge Sessions – Equipment and Materials Benefits

Upon estimating the initial equipment and materials benefits of the project, the Project Team conducted a series of challenge sessions with station SMEs and representatives of the Owner's Project Management and Finance Organizations. In the challenge sessions, the Project Team presented the approach and methodology used to collect, synthesize, and analyze the data to produce the equipment and material benefits. The attendees were encouraged to challenge any of the data, assumptions, or results presented during the session. The Project Team offered clarifications and any feedback was incorporated back into the BCA model.

## 4.6 Lessons Learned

Table A-7: Lessons Learned – Estimation of materials benefits.

| Number | Lesson Learned |
|---|---|
| 4-1 | The station's WMS system did not provide reliable cost data for components utilized in the field. The Project Team needed to look at purchasing data from the station's purchasing system. |
| 4-2 | To value inventory, the Project Team needed to determine the growth rate associated with components for each system. This was done by calculating the weighted average CAGR for a sample set of components. The key finding was that the cost of analog components making up the legacy systems are escalating at higher rates than what would be typically expected. |
| 4-3 | In some cases, components were common to multiple systems. In these cases, the team examined the materials data to assign an allocation of the component's historical usage and cost to the affected systems. |
| 4-4 | The WMS data provided a list of catalog items used that were expendable in nature (e.g., grease, hardware, fuses). Such items were not attributable to any system, in fact could be used in one of many applications within the station. As such, these items were excluded from the data as they were manually reviewed. To determine the cost benefits for miscellaneous, sundry, and consumable items, the Project Team provided a factored estimate and added this estimate back to the materials cost estimate. |

**DISCUSSION TOPIC: One-Time Write-Off of Obsolete Inventory and Equipment**
*In cases where implementation of a project will strand obsolete parts and equipment, these items should be assessed to determine if they can be sold and/or written of the books. The analyst should consult with the Owner's finance team to determine proper treatment of these one-time benefits. In some cases, this benefit is written as part of the capital project as an offset of costs and care should be taken not to double-count this on both sides of the Cost Benefit Analysis.*

# 5. Financial Analysis and Valuation of BCA

Based on the methodology and insights described in previous sections, financial models were applied to provide the Owner with key metrics to evaluate the viability of the project. The inputs to these models were the results of the analysis described in prior sections of this documents. The outputs included industry-standard financial analytics, including the project's NPV, IRR, and Payback Period.

## 5.1 Project Team Financial Model

A financial model was developed to incorporate one-time project costs associated with the project as well as ongoing, incremental annual O&M costs over the plant's anticipated license period. The financial model utilized a discounted cash flow methodology. The model incorporated three central elements to determine financial metric outputs:

- One-Time Project Costs
- Recurring Annual Costs and Benefits (and associated escalation rates)
- Net Present Value of Project.

A description of each of these elements and how they were implemented in the team's model is described in the following subsections. Templates with sample data are provided in Appendix B—Sheets 4.1-4.3 of this research product.

### 5.1.1 Summarizing Annual Labor and Material Benefits

Recurring annual benefits represent expected changes to the station's O&M expenses (including carrying cost of inventory[7]) resulting from project implementation. These annual benefits were estimated by the Project Team as illustrated in prior sections of this Appendix. A summary worksheet has been provided in Appendix B—Sheet 4.1 to consolidate annual benefits on a single sheet as input to financial cost-benefit models. (see below) illustrates the use of this worksheet with sample data provided for System 2.

| LABOR | System 1 | System 2 | System 3 | System 4 | Common | Total |
|---|---|---|---|---|---|---|
| ***Workload Reduction*** | | | | | | |
| Online Workload Reduction (Resource-Hrs.) | | 1,610 | | | | 1,610 |
| Outage Workload Reduction (Resource-Hrs.) | | 89 | | | | 89 |
| *Total Workload Reduction (Hrs.)* | | *1,699* | | | | *1,699* |
| ***Harvestable FTE*** | | | | | | |
| Harvestable Labor (FTE) - Resource 1 | | 2 | | | | 2 |
| Harvestable Labor (FTE) - Resource 2 | | -- | | | | 0 |
| Harvestable Labor (FTE) - Resource 3 | | 3 | | | | 3 |
| *Total Harvestable Labor (FTE)* | | *5* | | | | *5* |
| ***Annual Monetary Benefit ($ 2020)*** | | | | | | |
| Harvestable Labor Benefit ($) | 0 | 750,000 | 0 | 0 | 0 | 750,000 |
| Contract Labor ($) | | 152,390 | | | | 152,390 |
| Overtime ($) | | 4,672 | | | | 4,672 |
| **TOTAL ANNUAL LABOR BENEFIT** | **0** | **907,062** | **0** | **0** | **0** | **907,062** |

| MATERIALS AND TOOLS | System 1 | System 2 | System 3 | System 4 | Common | Total |
|---|---|---|---|---|---|---|
| ***Estimate Basis*** | | | | | | |
| Current Value of Inventory | | 3,000,000 | | | | 3,000,000 |
| Escalation Rate | | 18% | | | | n/a |
| ***Annual Cost of Materials*** | | | | | | |
| Annual Purchases of Materials | | 400,000 | | | | 400,000 |
| Misc. Sundry and Consumable Items | | 9,000 | | | | 9,000 |
| Carrying Cost | | 300,000 | | | | 300,000 |
| **TOTAL ANNUAL MATERIALS BENEFIT** | **0** | **709,000** | **0** | **0** | **0** | **709,000** |
| | | | | | | |
| **TOTAL ANNUAL BENEFIT** | **0** | **1,616,062** | **0** | **0** | **-** | **1,616,062** |

Figure A-15: Illustration of annual labor and materials benefits summary

### 5.1.2 One-Time and Ongoing Project Costs

The estimate of one-time installation and ongoing O&M costs associated with installing and operating the proposed modernized system were provided by the Owner to the Project Team. The estimates were based on parametrics and scaling of costs from similar modernization efforts conducted on non-safety systems. The Owner also considered additional costs associated with licensing and engineering the project to meet regulatory requirements. The estimates provided were based on the scope and benefits described in this research product and have not been validated against a selected solution at the time of this writing.

7. For the purposes of this research product, expected recurring O&M costs associated with the modernization of safety-related systems were provided by the Owner to facilitate the financial analysis. The project development team did not participate in the development or analysis of the recurring O&M cost estimate.

A worksheet has been provided in Appendix B—Sheet 4.2 to consolidate estimates for one-time project capital costs and ongoing operating costs on a single sheet as input to financial cost-benefit models. Figure A-16 (see below) illustrates the use of this worksheet with sample data provided.

**Project Capital and Ongoing Operating Cost Summary**

| | | |
|---|---|---|
| Current Year (Year 0) | 2020 | |
| Project Lifecycle | 20 | years |

| Project Installed and Ongoing Costs | | | | |
|---|---|---|---|---|
| System (Unit) | Installed Cost (thousands) | Ongoing O&M Cost (thousands) | Escalation of Labor and Materials | Year Cost Initiated |
| **One Time Project Costs (thousands)** | | | | |
| Project Development | $ 4,000 | | | |
| Engineering | $ 18,000 | | | |
| Equipment | $ 23,000 | | | |
| Construction | $ 18,000 | | | |
| Other | $ (500) | | | |
| | $ - | | | |
| **Ongoing Operating and Maintenance Cost** | | | | |
| Unit 1 PPS | | $ 25.00 | 4% | 2023 |
| Unit 2 DAS/DCS | | $ 12.00 | 4% | 2023 |
| Unit 1 Other | | $ 6.00 | 4% | 2023 |
| Unit 2 PPS | | $ 25.00 | 4% | 2025 |
| Unit 2 DAS/DCS | | $ 12.00 | 4% | 2025 |
| Unit 2 Other | | $ 6.00 | 4% | 2025 |
| | | | | |
| **Total Cost** | **62,500** | **$ 86.00** | | **Nominal Cash Flows:** |

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| System (Unit) | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 |
| **One Time Project Costs (thousands)** | | | | | | | | | | | | | | | | |
| Project Development | 4,000 | | | | | | | | | | | | | | | |
| Engineering | 5,000 | 8,000 | 5,000 | | | | | | | | | | | | | |
| Equipment | | | 9,000 | 7,000 | 4,000 | 3,000 | | | | | | | | | | |
| Construction | | | 4,000 | 6,000 | 6,000 | 2,000 | | | | | | | | | | |
| Other | | | | | (250) | | (250) | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| **Ongoing Operating and Maintenance Cost** | | | | | | | | | | | | | | | | |
| Unit 1 PPS | - | - | - | 28 | 29 | 30 | 32 | 33 | 34 | 36 | 37 | 38 | 40 | 42 | 43 | 45 |
| Unit 2 DAS/DCS | - | - | - | 13 | 14 | 15 | 15 | 16 | 16 | 17 | 18 | 18 | 19 | 20 | 21 | 22 |
| Unit 1 Other | - | - | - | 7 | 7 | 7 | 8 | 8 | 8 | 9 | 9 | 9 | 10 | 10 | 10 | 11 |
| Unit 2 PPS | - | - | - | - | - | 30 | 32 | 33 | 34 | 36 | 37 | 38 | 40 | 42 | 43 | 45 |
| Unit 2 DAS/DCS | - | - | - | - | - | 15 | 15 | 16 | 16 | 17 | 18 | 18 | 19 | 20 | 21 | 22 |
| Unit 2 Other | - | - | - | - | - | 7 | 8 | 8 | 8 | 9 | 9 | 9 | 10 | 10 | 10 | 11 |
| | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Total Cost** | **9,000** | **8,000** | **18,000** | **13,048** | **9,800** | **5,105** | **(141)** | **113** | **118** | **122** | **127** | **132** | **138** | **143** | **149** | **155** |

| Year | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| System (Unit) | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 |
| **One Time Project Costs (thousands)** | | | | | | | | | | | | | | | |
| Project Development | | | | | | | | | | | | | | | |
| Engineering | | | | | | | | | | | | | | | |
| Equipment | | | | | | | | | | | | | | | |
| Construction | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **Ongoing Operating and Maintenance Cost** | | | | | | | | | | | | | | | |
| Unit 1 PPS | 47 | 49 | 51 | 53 | 55 | 57 | 59 | - | - | - | - | - | - | - | - |
| Unit 2 DAS/DCS | 22 | 23 | 24 | 25 | 26 | 27 | 28 | - | - | - | - | - | - | - | - |
| Unit 1 Other | 11 | 12 | 12 | 13 | 13 | 14 | 14 | - | - | - | - | - | - | - | - |
| Unit 2 PPS | 47 | 49 | 51 | 53 | 55 | 57 | 59 | 62 | 64 | - | - | - | - | - | - |
| Unit 2 DAS/DCS | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 30 | 31 | - | - | - | - | - | - |
| Unit 2 Other | 11 | 12 | 12 | 13 | 13 | 14 | 14 | 15 | 15 | - | - | - | - | - | - |
| | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Total Cost** | **161** | **168** | **174** | **181** | **188** | **196** | **204** | **106** | **110** | **-** | **-** | **-** | **-** | **-** | **-** |

Figure A-16: Illustration of project capital and ongoing operating Cost Summary Worksheet.

### 5.1.3 Cost-Benefit Analysis

#### *5.1.3.1 Determining Future Cash Flows*

As illustrated in prior sections of this Appendix, the Project Team analyzed station data to determine the expected annual cost reductions for the current year and cast these benefits into future years utilizing escalation rates determined by the team. These Future Cash Flows (FCF) resulting from labor and material benefits are calculated as follows:

$$(FCF_{Direct\ Labor})_n = (No. of\ Harvestable\ FTEs \times Annual\ Labor\ Rate) \times (1 + Escalation\ Rate)^n$$

$$(FCF_{Materials})_n = (Estimated\ Annual\ Benefit) \times (1 + Escalation\ Rate)^n$$

In a similar manner, FCF can be forecast for other recurring benefits and costs, including outage contract labor, overtime savings, and carrying cost of inventory for each of the systems analyzed.

#### *5.1.3.2 Determining Present Value of Future Cash Flows*

Once expected cash flows from both one-time and recurring project costs and benefits have been tabulated in the financial model for each of the cost and benefit value streams, the PV (i.e., the value of the future cash flow in present dollars) for each of the value streams can be determined by discounting the FCF by a discount rate. In this case, the discount rate is equal to Owner's Cost of Capital (CoC). The CoC represents the lost opportunity for the Owner to place capital in alternative investments in lieu of this project. The PV of each cash flow can be calculated as follows:

$$PV_{Benefit(Cost)} = \sum_{n=0}^{n=\ Final\ Year} \frac{(FCF_{Benefit(Cost)})_n}{(1 + Cost\ of\ Capital)^n}$$

Where:

$PV_{Benefit(Cost)} = Present\ Value\ of\ the\ Cash\ Flow\ Stream$

$FCF_{Benefit(Cost)} = Current\ Average\ Annual\ Material\ Expenditure$

$Cost\ of\ Capital = Cost\ of\ Capital\ (by\ Owner)$

$n = Nominal\ Year$

$Final\ Year = Year\ project\ lifecycle\ ends\ (defined\ by\ project\ team)$

#### *5.1.3.3 Determining Net Present Value*

To calculate the NPV of the project, the team summed the PV calculated for each cash flow stream:

$$NPV_{Project} = \sum PV_{Benefit(Cost)}$$

The resulting value can either be positive or negative, and the resulting implications of each of these values is explained in the Table A-8 (see below):

Table A-8: NPV outcomes and implications.

| If the NPV is … | Then the business case… |
|---|---|
| Positive (i.e., greater than or equal to zero) | Is favorable for the project investment. This implies that the project is expected to return more free cash to the utility as an investment, generating the Owner's CoC |
| Negative (i.e., less than zero) | Is not favorable for the project investment. This implies that the project will return less free cash to the utility as an investment, generating the Owner's CoC |

The Cost-Benefit Analysis Worksheet provided in Appendix B—Sheet 4.3 is a template that may be used to calculate the project NPV. One-time and recurring costs and benefits recorded on Sheets 4.1 and 4.2 are translated into the tables provided in the worksheet. Escalation rates for labor and materials are also entered. Additionally, the user will select the expected project lifecycle and provide information as to the year the cost or benefit is expected to occur. The worksheets are designed to be flexible enough to be aligned with installation plans (e.g., execution of the modernization over multiple years). Once the data inputs are completed, the worksheet then calculates the PV of each cost category and the NPV of the project. An illustration of the Cost-Benefit Analysis Worksheet is provided in Figure A-17 (see below).

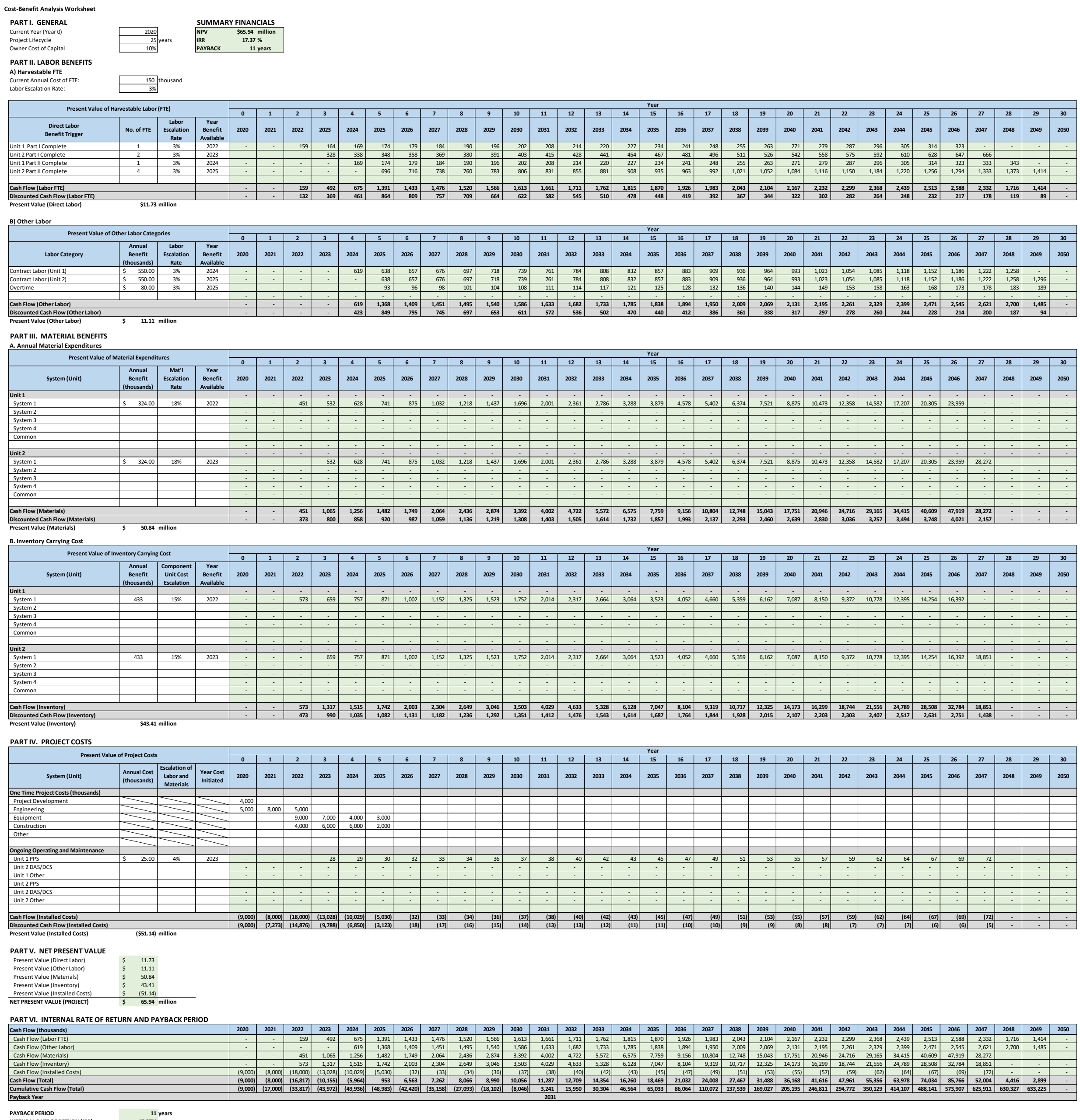

Figure A-17: Illustration of project financial analysis worksheet.

### 5.1.4 Internal Rate of Return

The IRR of the project is the Return on Capital (ROC) required for the NPV of the upgrade to be zero. It inverts the concept of an NPV calculation and instead calculates the project's ROC. This analysis enables the model to determine if the project meets the utility's ROC requirements. How to consider an IRR analysis is outlined in Table A-9 (see below):

Table A-9 IRR outcomes and implications.

| If the IRR is … | Then the business case… |
|---|---|
| Positive (i.e., greater than or equal to CoC) | Is favorable for the project investment. This implies that the return of the project is greater than the utility's ROC. |
| Negative (i.e., less than zero) | Is not favorable for the project investment. This implies that the return of the project is less than the utility's ROC. |

The IRR is calculated on the Cost-Benefit Analysis Worksheet as part of the summary financials in Appendix B—Sheet 4.3.

### 5.1.5 Payback Analysis

To calculate the project payback period, the team started with the FCF at the initial investment period (Year 0). This value was negative due to upfront project costs. Then, the team cumulatively summed the FCFs for each following year. The payback period is calculated as the amount of time required for the cumulative sum of the FCFs to exceed zero.

The Payback Period is calculated on the Cost-Benefit Analysis Worksheet as part of the summary financials in Appendix B—Sheet 4.3. Additionally, the worksheet also provides a graphic display of the project cumulative cash flows as illustrated in Figure A-18 (see below).

This is sometimes referred to as a "break-even" analysis. Generally, a project can have multiple years of negative FCFs before having years of positive FCFs. It does not consider any ROC rate and does not discount FCFs to their PV. As a result, FCFs after Year 0 are inflated in a payback analysis compared to those in an NPV analysis.

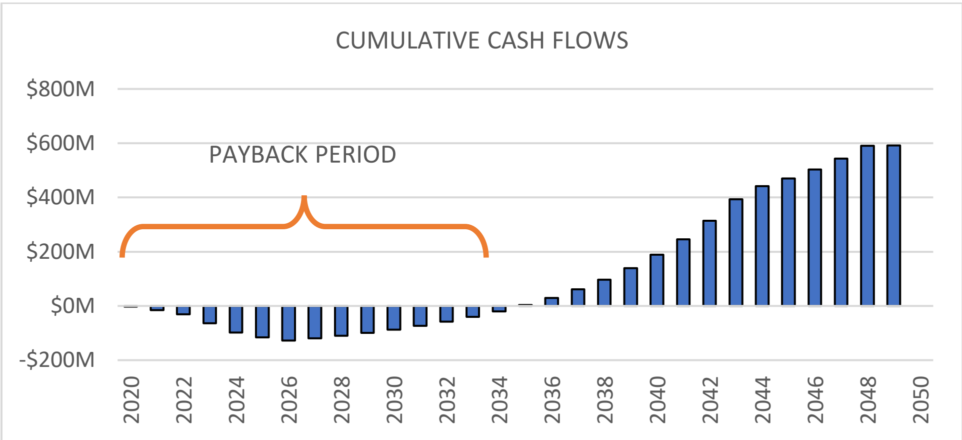


Figure A-18: Illustration of cumulative cash flow chart on Cost-Benefit Analysis Worksheet.

## 5.2 Lessons Learned

Table A-10: Lessons Learned – Financial analysis and valuation.

| Number | Lesson Learned |
|---|---|
| 5-1 | To determine escalation rates associated with material expenditures for each system, the Project Team needed examined growth of total annual material expenditures for each system. This was done by calculating the CAGR of material expenditures over a 15-year period. The key finding was that material expenditures to support maintenance of legacy systems are escalating at higher rates than what would be typically expected. |

# Appendix B: Business Case Analysis (BCA) Workbook

# APPENDIX B:
# BUSINESS CASE ANALYSIS (BCA) WORKBOOK

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- 1.4 Surveillance and Test List

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**4. Cost-Benefit Analysis Templates**
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- 4.3 Project Financial Analysis Worksheet

SAMPLE FIGURES PROVIDED IN THIS APPENDIX ARE FOR ILLUSTRATIVE PURPOSES AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA

## Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations

**Appendix B - Sheet 1.1**

**In-Scope Equipment List Template**

| Equipment Tag Number | Equipment Description | Device Type | System Code | Primary System | Sub-System | In-Scope (Y/N) | Notes |
|---|---|---|---|---|---|---|---|
| PDIS-049-1N657A | RCIC HI STEAM PRESSURE SW | Differential Pressure Indicating Switch | 051 | ECCS | RCIC | Y | |
| | | | | | | | |
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**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 1.2**

**In-Scope System List Template**

| System Code | Primary System | Subsystem |
|---|---|---|
| 001 | NSSSS | Main Steam |
| 025 | NSSSS | Temp Monitoring |
| 026 | NSSSS | RMMS |
| 036 | ATWS MS | Primary System |
| 041 | ECCS | Main Steam/ADS |
| 042 | Common | Nuclear Boiler Instr |
| 044 | NSSSS | RWCU |
| 046 | RPS | CRD |
| 048 | ATWS MS | SLC |
| 049 | ECCS | RCIC |
| 050 | ECCS | ADS |
| 051 | ECCS | RHR |
| 052 | ECCS | Core Spray |
| 055 | ECCS | HPCI |
| 056 | ECCS | HPCI |
| 059 | NSSSS | PCIG & TIP Pwr Supply |
| 071 | RPS | Primary System |
| 072 | NSSSS | Primary System |
| 076 | NSSSS | HVAC |
| 092 | ECCS | 4kV and EDGs |

**Notes:**

| Primary System | Primary System Full Name |
|---|---|
| RPS | Reactor Protection System |
| ATWS MS | Anticipated Transient Without Scram Mitigation System |
| ECCS | Emergency Core Cooling System |
| NSSSS | Nuclear Steam Supply Shutoff System |

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 1.3**

**PMI List Template**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

| PMID Number | PMI Title | PMI Status | PMI Frequency Code | Equipment Tag Number | In-Scope (Y/N) | Annual Frequency | Online or Outage | Notes |
|---|---|---|---|---|---|---|---|---|
| 221381 | (10-C609) AGASTAT RELAY END OF LIFE REPLACEMENT | ACTIVE | O2 | 10-C609 | Y | 0.25 | Outage | |
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**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 1.4**

**Surveillance and Test (ST) List**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

| ST Number | Revision | Tech Spec Requirement | ST Description | Unit | PMID Number | PMI Status | PMI Frequency Code | PMI Frequency (Annual) | Online or Outage | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| ST-2-074-XXX-1 | Rev. 007 | T.4.3.1-X.X | LOGIC SYSTEM FUNCTIONAL TEST OF RPS APRM OPRM 2-OUT-OF-4 VOTER | 001 | 2010203 | ACTIVE | O1 | 0.5 | Outage | |
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**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 2.1**

**Surveillance and Test (ST) Workload Reduction Worksheet**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

| PMI LEVEL DATA | | | | | | | | | ST WO TASK LEVEL DATA | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Tech Spec | ST No. | PMI Description | PMID No. | No. of PMIs | PMI Frequency (Annual) | Total PMI per Year | Online or Outage | System | Online or Outage | No. of PMIs with Task | PMI Frequency (Annual) | No. Times Task Performed | Task Description | Task included in ST WO | Functional Area | Work Group | Resource Type | No. Resource Req'd | Task Duration (Hrs) | Task Workload (Resource-Hrs) | Annual Workload (Resource-Hrs) | % Workload Reduction (Estimated) | Annual Workload Reduction (Resource-Hrs) | Other comments |
| **1.0.** | **RPS** | | | | | | | | | | | | | | | | | | | | | | | | |
| **1.1.** | **T.4.3.1-1.3** | **High Steam Dome Pressure** | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1.1. | T.4.3.1-1.3 | ST-2-042-645-* | High Steam Dome Pressure Function | 243199 | 4 | 2 | 8 | Online | RPS | Online | 4 | 2.00 | 1 | Field Work | Y | MA | I&C | Craft | 2.00 | 1.00 | 2.00 | 16.00 | 100% | 16.00 | |
| | | ST-2-042-646-* | | 243201 | | | | | RPS | Online | 4 | 2.00 | 1 | Scheduling | N | MA | Maint Prep | Scheduler | 1.00 | 1.00 | 1.00 | 8.00 | 100% | 8.00 | |
| | | ST-2-042-647-* | | 243203 | | | | | RPS | Online | 4 | 2.00 | 1 | Work Planning/Coord. | N | WM | Maint Prep | Planner | 1.00 | 1.00 | 1.00 | 8.00 | 100% | 8.00 | |
| | | ST-2-042-648-* | | 243205 | | | | | RPS | Online | 4 | 2.00 | 1 | Print Out Procedures | N | MA | I&C | Clerical | 1.00 | 0.13 | 0.13 | 1.00 | 100% | 1.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | Load into EWP | N | MA | I&C | Supervisor | 1.00 | 0.13 | 0.13 | 1.00 | 100% | 1.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | Pre-Job Brief/Prep | N | OP | Shift Ops | SRO | 1.00 | 0.25 | 0.25 | 2.00 | 100% | 2.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | Pre-Job Brief/Prep | N | OP | Shift Ops | RO | 1.00 | 0.25 | 0.25 | 2.00 | 100% | 2.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | WO Closeout | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 2.00 | 100% | 2.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | Grade ST | N | MA | Maint Prep | Supervisor | 1.00 | 0.25 | 0.25 | 2.00 | 100% | 2.00 | |
| | | | | | | | | | RPS | Online | 4 | 2.00 | 1 | Maintain Records | N | MA | Maint Prep | Clerical | 1.00 | 0.25 | 0.25 | 2.00 | 100% | 2.00 | |

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 2.2**

**Preventive Maintenance (PM) Workload Reduction Worksheet**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

| PMI LEVEL DATA | | | | | | | | | PM WO TASK LEVEL DATA | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Equipment Type | PMI Description | Ref. Equipment Tag | PMID No. | No. of PMIs | PMI Frequency (Annual) | Total PMI per Year | Online or Outage | System | Online or Outage | WO Task No. | No. of PMIs with Task | PMI Frequency (Annual) | No. Times Task Performed | Task Description | Task included in PM WO | Functional Area | Work Group | Resource Type | No. Resource Req'd | Task Duration (Hrs) | Total Task Labor (Hrs) | Total Time (Annual) | % Workload Reduction (Estimated) | Annual Workload Reduction (Resource-Hrs) | Other comments |
| **1.0 RPS** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **1.1. Routine Relay Replacement** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1.1. | Instrument | Routine Relay Replacement | C71A-K03C | 219474 | 36 | 0.025 | 0.88 | Outage | RPS | Outage | 1 | 36 | 0.025 | 1.00 | Pre-outage Bench Calibration | Y | MA | I&C | Craft | 1.00 | 4.00 | 4.00 | 3.60 | 100% | 3.60 | |
| | | | C71A-K01A | 219475 | | | | | RPS | Outage | 2 | 36 | 0.025 | 1.00 | Replacement | Y | MA | I&C | Craft | 2.00 | 6.00 | 12.00 | 10.80 | 100% | 10.80 | |
| | | | C71A-K01B | 219476 | | | | | RPS | Outage | 3 | 36 | 0.025 | 1.00 | Perform Test | Y | MA | I&C | Craft | 2.00 | 6.00 | 12.00 | 10.80 | 100% | 10.80 | |
| | | | C71A-K01C | 219477 | | | | | RPS | Outage | 4 | 36 | 0.025 | 1.00 | Update Component Record Label | Y | WM | Maint Prep | Planner | 2.00 | 4.00 | 8.00 | 7.20 | 100% | 7.20 | |
| | | | C71A-K01D | 219478 | | | | | RPS | Outage | | 36 | 0.025 | 1.00 | WO Task Closeout | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 0.23 | 100% | 0.23 | |
| | | | C71A-K03A | 219479 | | | | | RPS | Outage | 5 | 36 | 0.025 | 1.00 | Pre-outage Tech Review | Y | MA | I&C | Craft | 1.00 | 16.00 | 16.00 | 14.40 | 100% | 14.40 | |
| | | | C71A-K03B | 219480 | | | | | RPS | Outage | 6 | 4 | 0.025 | 1.00 | Stage Equipment | Y | MA | I&C | Craft | 2.00 | 8.00 | 16.00 | 1.60 | 100% | 1.60 | |
| | | | C71A-K03D | 219481 | | | | | RPS | Outage | 7 | 4 | 0.025 | 1.00 | Build Non-Conductive Platform | Y | MA | Support | Craft | 2.00 | 24.00 | 48.00 | 4.80 | 100% | 4.80 | |
| | | | C71A-K03E | 219482 | | | | | RPS | Outage | 8 | 8 | 0.025 | 1.00 | APRM1 Time Response PMT (C71A-K12A thru H) | Y | MA | I&C | Craft | 2.00 | 6.00 | 12.00 | 2.40 | 100% | 2.40 | |
| | | | C71A-K03F | 219483 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | Pre-Job Brief | N | OP | Shift Ops | RO | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K03G | 219484 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | Pre-Job Brief | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K03H | 219485 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | WO Task Closeout | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K08A | 219486 | | | | | RPS | Outage | 9 | 8 | 0.025 | 1.00 | OPRM1 Time Response PMT (C71A-K12A thru H) | Y | MA | I&C | Craft | 2.00 | 6.00 | 12.00 | 2.40 | 100% | 2.40 | |
| | | | C71A-K08B | 219487 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | Pre-Job Brief | N | OP | Shift Ops | RO | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K08C | 219488 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | Pre-Job Brief | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K08D | 219489 | | | | | RPS | Outage | | 8 | 0.025 | 1.00 | WO Task Closeout | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 0.05 | 100% | 0.05 | |
| | | | C71A-K10A | 219490 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | Scheduling and Coordination | N | MA | Maint Prep | Scheduler | 1.00 | 1.00 | 1.00 | 4.50 | 100% | 4.50 | |
| | | | C71A-K10B | 219491 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | Print Out Procedures (Tasks 1-3, 5, 7) | N | MA | I&C | Clerical | 1.00 | 0.50 | 0.50 | 2.25 | 100% | 2.25 | |
| | | | C71A-K10D | 219492 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | Load into EWP (Tasks 1-3, 5, 7) | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 1.13 | 100% | 1.13 | |
| | | | C71A-K10D | 219493 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | Pre-Job Brief (Tasks 1-3, 5, 7) | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 1.13 | 100% | 1.13 | |
| | | | C71A-K10E | 219494 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | Pre-Job Brief (Tasks 1-3, 5, 7) | N | OP | Shift Ops | RO | 1.00 | 0.25 | 0.25 | 1.13 | 100% | 1.13 | |
| | | | C71A-K10F | 219495 | | | | | RPS | Outage | | 36 | 0.025 | 5.00 | WO Task Closeout (Tasks 1-3, 5, 7) | N | MA | I&C | Supervisor | 1.00 | 0.25 | 0.25 | 1.13 | 100% | 1.13 | |
| | | | C71A-K10G | 219496 | | | | | RPS | Outage | | 36 | 0.025 | 1.00 | Ops Support/Review | N | OP | Shift Ops | RO | 1.00 | 0.50 | 0.50 | 0.45 | 100% | 0.45 | |
| | | | C71A-K10H | 219497 | | | | | RPS | Outage | | 36 | 0.025 | 1.00 | Ops Support/Review | N | OP | Shift Ops | SRO | 1.00 | 0.50 | 0.50 | 0.45 | 100% | 0.45 | |
| | | | C71A-K12A | 219498 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12B | 219499 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12C | 219500 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12D | 219501 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12E | 219502 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12F | 219503 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12G | 219504 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K12H | 219505 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K33A | 225516 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K33B | 225517 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K33C | 225518 | | | | | | | | | | | | | | | | | | | -- | | -- | |
| | | | C71A-K33D | 225520 | | | | | | | | | | | | | | | | | | | -- | | -- | |
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| **1.2. Agastat Relay Replacement** | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 2.3**

**Corrective Maintenance (CM) Labor Workload Reduction Worksheet**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

| CM WO TASK LEVEL DATA | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **System Name** | **System No.** | **Equipment Number** | **Equipment Name** | **Device Type** | **WO No.** | **WO Description** | **System** | **WO Task No.** | **WO Task Title** | **Functional Area** | **Work Group** | **Resource Type** | **Staff Req'd** | **Hrs. per Person** | **Estimated Labor Hrs.** |
| ECCS - 4kV and EDGs | 92 | 162Z-11609 | 101-D12 SAFEGUARD XFMR BREAKER FEEDER BUS UNDERVOLTAGE AUX RELAY | Relay | 4587294 | 162Z-11609 NOT CHANGING STATE DURING ST-2-0923-322-1 | ECCS | 01 | 162Z-11609 (LMI3) BENCH CALIBRATE RELAY | MA | I&C | Craft | 1 | 4 | 4 |
| | | | | | | | ECCS | 02 | 162Z-11609 (LMI3) REPLACE UNDERVOLTAGE | MA | I&C | Craft | 1 | 4 | 4 |
| | | | | | | | ECCS | 03 | 162Z-11609 NOT CHANGING STATE DURING ST-2-0923-322-1 | MA | I&C | Craft | 1 | 4 | 4 |
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**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 2.4**

**ST Workload Reduction Summary**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

**Annual Workload Reduction (Hrs.) by Labor Category (2 Units)**

| Labor Category | | | System 1 | | System 2 | | System 3 | | System 4 | | Common | | Total Hrs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Functional Area | Work Group | Resource Type | Online Workload Reduction | Outage Workload Reduction | Online Workload Reduction | Outage Workload Reduction | Online Workload Reduction | Outage Workload Reduction | Online Workload Reduction | Outage Workload Reduction | System 042 Workload Reduction | Shift Rounds Workload Reduction | |
| MA | I&C | Supervisor | | | 114.00 | 3.00 | | | | | | | 117.00 |
| MA | I&C | Craft | | | 1,336.24 | 500.60 | | | | | | | 1,836.84 |
| MA | I&C | Clerical | | | 38.00 | 1.00 | | | | | | | 39.00 |
| MA | Electrical | Supervisor | | | - | - | | | | | | | - |
| MA | Electrical | Craft | | | - | - | | | | | | | - |
| MA | Electrical | Clerical | | | - | - | | | | | | | - |
| MA | Mechanical | Craft | | | - | - | | | | | | | - |
| MA | Support | Craft | | | - | - | | | | | | | - |
| MA | CMO | Technician | | | - | - | | | | | | | - |
| MA | Reactor Services | Technician | | | - | - | | | | | | | - |
| MA | Maint Prep | Supervisor | | | 76.00 | 2.00 | | | | | | | 78.00 |
| MA | Maint Prep | Scheduler | | | 329.34 | - | | | | | | | 329.34 |
| MA | Maint Prep | Clerical | | | 76.00 | 2.00 | | | | | | | 78.00 |
| WM | Maint Prep | Planner | | | 329.34 | - | | | | | | | 329.34 |
| WM | Outage Mgmt | Scheduler | | | - | 18.50 | | | | | | | 18.50 |
| WM | Outage Mgmt | Planner | | | - | 13.50 | | | | | | | 13.50 |
| OP | Shift Ops | SRO | | | 76.00 | 2.50 | | | | | | | 78.50 |
| OP | Shift Ops | RO | | | 108.00 | 4.80 | | | | | | | 112.80 |
| OP | Shift Ops | EO | | | 64.00 | 13.10 | | | | | | | 77.10 |
| OP | Support | Scheduler | | | - | - | | | | | | | - |
| OP | Services | Planner | | | - | - | | | | | | | - |
| OP | Services | Clerical | | | - | - | | | | | | | - |
| OP | Reactor Eng | Engineer | | | - | - | | | | | | | - |
| EN | Syst Eng | Supervisor | | | - | - | | | | | | | - |
| EN | Syst Eng | Engineer | | | - | - | | | | | | | - |
| RP | Support | Technician | | | - | - | | | | | | | - |
| CY | Chemistry | Technician | | | - | - | | | | | | | - |
| CA | Various | Various | | | - | - | | | | | | | - |
| TR | Ops | Various | | | - | - | | | | | | | - |
| TR | Maint | Various | | | - | - | | | | | | | - |
| IT | IT | Analyst | | | - | - | | | | | | | - |
| **TOTAL:** | | | **-** | **-** | **2,546.92** | **561.00** | **-** | **-** | **-** | **-** | **-** | **-** | **3,107.92** |

Check: 3,107.92 OK

**Summary Statistics (2 Units)**

| Summary Statistic | System 1 | System 2 | System 3 | System 4 | Common | Total |
|---|---|---|---|---|---|---|
| No. of In-Scope PMI Identified | | 34 | | | | 34 |
| No. PMI Performed per Year | | 17 | | | | 17 |
| Total In-Scope Annual Workload | | 632 | | | | 632 |
| Average Labor Hours per ST WO* | | 37 | | | | 37 |
| Labor Benefits Identified (Reduced Workload) | | 561 | | | | 561 |
| **Percent Workload Reduction** | **#DIV/0!** | **89%** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **89%** |

* Total Average Labor Hours per ST WO excludes Shift Rounds (Common)

## Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations

**Appendix B - Sheet 2.5**

**PM Workload Reduction Summary**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

**Annual Workload Reduction (Hrs.) by Labor Category (2 Units)**

| Labor Category | | | System 1 | | System 2 | | System 3 | | System 4 | | Common | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Functional Area | Work Group | Resource Type | Online Workload Reduction | Outage Workload Reduction | Online Workload Reduction | Outage Workload Reduction | Online Workload Reduction | Outage Workload Reduction | Online Workload Reduction | Outage Workload Reduction | System 042 Workload Reduction | Shift Rounds Workload Reduction | Total Hrs. |
| MA | I&C | Supervisor | | | - | 5.15 | | | | | | | 5.15 |
| MA | I&C | Craft | | | - | 457.83 | | | | | | | 457.83 |
| MA | I&C | Clerical | | | - | 4.08 | | | | | | | 4.08 |
| MA | Electrical | Supervisor | | | - | - | | | | | | | - |
| MA | Electrical | Craft | | | - | - | | | | | | | - |
| MA | Electrical | Clerical | | | - | - | | | | | | | - |
| MA | Mechanical | Craft | | | - | - | | | | | | | - |
| MA | Support | Craft | | | - | - | | | | | | | - |
| MA | CMO | Technician | | | - | - | | | | | | | - |
| MA | Reactor Services | Technician | | | - | - | | | | | | | - |
| MA | Maint Prep | Supervisor | | | - | - | | | | | | | - |
| MA | Maint Prep | Scheduler | | | - | 2.64 | | | | | | | 2.64 |
| MA | Maint Prep | Clerical | | | - | - | | | | | | | - |
| WM | Maint Prep | Planner | | | - | - | | | | | | | - |
| WM | Outage Mgmt | Scheduler | | | - | - | | | | | | | - |
| WM | Outage Mgmt | Planner | | | - | - | | | | | | | - |
| OP | Shift Ops | SRO | | | - | - | | | | | | | - |
| OP | Shift Ops | RO | | | - | - | | | | | | | - |
| OP | Shift Ops | EO | | | - | - | | | | | | | - |
| OP | Support | Scheduler | | | - | - | | | | | | | - |
| OP | Services | Planner | | | - | - | | | | | | | - |
| OP | Services | Clerical | | | - | - | | | | | | | - |
| OP | Reactor Eng | Engineer | | | - | - | | | | | | | - |
| EN | Syst Eng | Supervisor | | | - | 0.50 | | | | | | | 0.50 |
| EN | Syst Eng | Engineer | | | - | 16.00 | | | | | | | 16.00 |
| RP | Support | Technician | | | - | - | | | | | | | - |
| CY | Chemistry | Technician | | | - | - | | | | | | | - |
| CA | Various | Various | | | - | - | | | | | | | - |
| TR | Ops | Various | | | - | - | | | | | | | - |
| TR | Maint | Various | | | - | - | | | | | | | - |
| IT | IT | Analyst | | | - | - | | | | | | | - |
| **TOTAL:** | | | **-** | **-** | **-** | **486.19** | **-** | **-** | **-** | **-** | **-** | **-** | **486.19** |

Check: 486.19 OK

**Summary Statistics (2 Units)**

| Summary Statistic | System 1 | System 2 | System 3 | System 4 | Common | Total |
|---|---|---|---|---|---|---|
| No. of In-Scope PMI Identified | 160 | 10 | 60 | 38 | n/a | 352 |
| No. PMI Performed per Year | 10.0 | 4.1 | 6.7 | 2.9 | n/a | 45 |
| Average Labor Hours per PMI | 44 | 117 | 60 | 75 | n/a | 48 |

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 2.6**

**CM Workload Reduction Summary**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

**Annual Workload Reduction (Hrs.) by Labor Category (2 Units)**

| Labor Category | | | System 1 | System 2 | System 3 | System 4 | Common | |
|---|---|---|---|---|---|---|---|---|
| Functional Area | Work Group | Resource Type | Online Workload Reduction | Online Workload Reduction | Online Workload Reduction | Online Workload Reduction | Online Workload Reduction | Total Hrs. |
| MA | I&C | Supervisor | | 9.46 | | | | 9.46 |
| MA | I&C | Craft | | 102.40 | | | | 102.40 |
| MA | I&C | Clerical | | 4.70 | | | | 4.70 |
| MA | Electrical | Supervisor | | 0.23 | | | | 0.23 |
| MA | Electrical | Craft | | 4.80 | | | | 4.80 |
| MA | Electrical | Clerical | | - | | | | - |
| MA | Mechanical | Craft | | - | | | | - |
| MA | Support | Craft | | - | | | | - |
| MA | CMO | Technician | | - | | | | - |
| MA | Reactor Services | Technician | | - | | | | - |
| MA | Maint Prep | Supervisor | | - | | | | - |
| MA | Maint Prep | Scheduler | | 5.20 | | | | 5.20 |
| MA | Maint Prep | Clerical | | - | | | | - |
| WM | Maint Prep | Planner | | 12.00 | | | | 12.00 |
| WM | Outage Mgmt | Scheduler | | - | | | | - |
| WM | Outage Mgmt | Planner | | - | | | | - |
| OP | Shift Ops | SRO | | 1.30 | | | | 1.30 |
| OP | Shift Ops | RO | | 5.20 | | | | 5.20 |
| OP | Shift Ops | EO | | - | | | | - |
| OP | Support | Scheduler | | - | | | | - |
| OP | Services | Planner | | - | | | | - |
| OP | Services | Clerical | | - | | | | - |
| OP | Reactor Eng | Engineer | | - | | | | - |
| EN | Syst Eng | Supervisor | | - | | | | - |
| EN | Syst Eng | Engineer | | - | | | | - |
| RP | Support | Technician | | - | | | | - |
| CY | Chemistry | Technician | | - | | | | - |
| CA | Various | Various | | - | | | | - |
| TR | Ops | Various | | - | | | | - |
| TR | Maint | Various | | - | | | | - |
| IT | IT | Analyst | | - | | | | - |
| **TOTAL:** | | | **-** | **145.29** | **-** | **-** | **-** | **145.29** |
| | | | | | | | | 145.29 |

| Key Statistics: | System 1 | System 2 | System 3 | System 4 | Common | Total |
|---|---|---|---|---|---|---|
| **Work Orders per Year (2 Units)** | | 5 | | | | |
| **WO Tasks per Year (2 Units)** | | 19 | | | | |
| **Hrs. per WO** | | 28 | | | | |
| **Hrs. per Task** | | 8 | | | | |

**Basis, Assumptions and Clarifications:**

1. Maintenance data gathered from plant work management system for in-scope systems.
2. Work management system data filtered for in-scope equipment with work order status closed dates between xxx 1, 2015 through xxx 30, 2019.
4. Ref. In-Scope Equipment List ver. Xxx
5. Additional Support Assumptions (added to totals above):

| | |
|---|---|
| Craft Supervision | 1 Hr. per WO; 15 minutes per WO Task |
| Clerical Support | 15 minutes per WO Task |
| Scheduling and Coordination | 1 hr. per WO |
| Planner | 2 hr. per WO |
| Ops Support | 1 hr. per WO |
| Ops Support SRO | 15 min per WO |

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 2.7**

**Event Management and Corrective Action Program Workload Reduction Worksheet**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

**PART I. SUMMARY EVENT MANAGEMENT AND CAP WORKLOAD ESTIMATE**

**No. of Events 2014-Present (Ref. "IR Scope Determination Workbook")**

| Event Classification | Number of Events (2014 to Present) | | | | |
|---|---|---|---|---|---|
| | System 1 | System 2 | System 3 | System 4 | Common |
| Class A (RCA) | | | | | |
| Class B (ACE) | 1.0 | - | 2.0 | 1.0 | - |
| Class D (WGE or no formal investigation) | | | | | |

**No. of Events per Year**

| Event Classification | Number of Events per Year | | | | |
|---|---|---|---|---|---|
| | System 1 | System 2 | System 3 | System 4 | Common |
| Class A (RCA) | | | | | |
| Class B (CAPE or EACE) | 0.2 | - | 0.3 | 0.2 | - |
| Class D (WGE or no formal investigation) | | | | | |

**Event Management and CAP Annual Hours**

| Event Classification | Workload (Hrs./Yr.) | | | | | Total |
|---|---|---|---|---|---|---|
| | System 1 | System 2 | System 3 | System 4 | Common | |
| Class A (RCA) | | | | | | |
| Class B (CAPE or EACE) | 65.3 | - | 130.5 | 65.3 | - | 261 |
| Class D (WGE or no formal investigation) | | | | | | |
| **TOTAL** | **65** | **-** | **131** | **65** | **-** | **261** |

**PART II. EVENT TYPE WORKLOAD ESTIMATE**

**Work Estimate (typ. Per Event Type)**

| Work Breakdown | Resource | | Class A (RCA) | | Class B (ACE) | | Class D (WGE) | | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Description (sample activities) | Function | Resource Type | No. of Persons | Duration (Hrs.) | No. of Persons | Duration (Hrs.) | No. of Persons | Duration (Hrs.) | |
| **1.0. Issue ID and Screening** | | | **Hrs./Event** | **0** | **Hrs./Event** | **29.25** | **Hrs./Event** | **0** | |
| *Issue identification (Field)* | *MGMT* | *SOC* | | | 8 | 0.25 | | | |
| *Supervisor Review* | *OP* | *Shift Manager* | | | 1 | 2 | | | |
| *Creation of CAP* | *OP* | *Supervisor* | | | 1 | 2 | | | |
| *Shift Manager Review* | *OP* | *RO* | | | 1 | 2 | | | |
| ` | *OP* | *EO* | | | 1 | 3 | | | |
| *Document comments on IR* | *MA* | *Supervisor* | | | 1 | 0.25 | | | |
| *Station Ownership Committee Review/Screening* | *MA* | *Technician* | | | 2 | 4 | | | |
| *Update Corrective Actions and assignments on CAP* | *MA* | *Craft* | | | 2 | 1 | | | |
| | *FIN* | *Engineer* | | | 1 | 8 | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **2.0. Event Response** | | | **Hrs./Event** | **0** | **Hrs./Event** | **148** | **Hrs./Event** | **0** | |
| *Establish Event Response Team (if req'd)* | *EN* | *Engineer* | | | 5 | 24 | | | |
| *Conduct Prompt Investigation* | *OP* | *Ops Services* | | | 1 | 12 | | | |
| | *MA* | *Planning* | | | 2 | 4 | | | |
| | *FIN* | *Craft* | | | 2 | 4 | | | |
| | | | | | | | | | |
| **3.0. Implement Corrective Actions** | | | **Hrs./Event** | **0** | **Hrs./Event** | **198** | **Hrs./Event** | **0** | |
| *MRC Reviews* | *MGMT* | *MRC* | | | 8 | 0.25 | | | |
| *Conduct Evaluation (RCA/CAPE/WGE)* | *EN* | *Engineer* | | | 1 | 112 | | | |
| *Prepare Evaluation Report* | *CA* | *Engineer* | | | 1 | 16 | | | |
| *Review Evaluation Reports* | *LS* | *Engineer* | | | 1 | 40 | | | |
| *Enter Assignments in CAP* | *OP* | *Writer* | | | 1 | 16 | | | |
| *Manage Actions* | *RM* | *Writer* | | | 1 | 8 | | | |
| *Complete Actions - Field Maint* | *MA* | *Planning* | | | 1 | 4 | | | |
| *Complete Actions - Admin/Regulatory Reports* | | | | | | | | | |
| *Complete Actions - Notifications* | | | | | | | | | |
| *Document Operating Experience* | | | | | | | | | |
| *Conduct Effectiveness Review* | | | | | | | | | |
| *Close out Corrective Actions* | | | | | | | | | |
| | | | **Total Hrs.** | **0** | **Total Hrs.** | **375.25** | **Total Hrs.** | **0** | |

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 2.8**

**Overtime Labor Worksheet (1 Sheet per System)**

| Labor Division | | | Total Workload Reduction (Hrs) | Potential Harvestable Resource? | Labor Rate ($/Hr) | OT Multiplier (x Labor Rate) | Overtime Cost |
|---|---|---|---|---|---|---|---|
| Functional Area | Work Group | Resource Type | | | | | |
| MA | I&C | Supervisor | 450 | No | 65.00 | 1.25 | 36,563 |
| | | Clerical | | No | | | 0 |
| | Electrical | Supervisor | | No | | | 0 |
| | | Craft | | No | | | 0 |
| | | Clerical | | No | | | 0 |
| | Mechanical | Craft | | No | | | 0 |
| | Support | Craft | | No | | | 0 |
| | CMO | Technician | | No | | | 0 |
| WM | Maint Prep | Planner | | Yes | | | n/a |
| | Outage Mgmt | Scheduler | | No | | | 0 |
| | | Planner | | No | | | 0 |
| OP | Support | Scheduler | | No | | | 0 |
| | Services | Planner | | No | | | 0 |
| | | Clerical | | No | | | 0 |
| **Total** | | | | | | | **$36,563** |

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**
**Appendix B - Sheet 2.9**
**Contract Labor Summary**

| Contractor | System | Annual Expenditure |
|---|---|---|
| Contractor 1 | | $56,000 |
| Contractor 2 | | $22,000 |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| **Total Annual Expense** | | **78,000** |

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**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 2.10**

**Annual Labor Workload Reduction Summary**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

| Labor Division | | | ONLINE LABOR WORKLOAD REDUCTION | | | | | | | | | | | | | | | | | | TOTAL ONLINE WORKLOAD REDUCTION | OUTAGE LABOR WORKLOAD REDUCTION | | | | | | | | TOTAL OUTAGE WORKLOAD REDCUTION | TOTAL WORKLOAD REDUCTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | System 1 | | | | System 2 | | | | System 3 | | | | System 4 | | | | Common | | | System 1 | | System 2 | | System 3 | | System 4 | | | |
| Functional Area | Work Group | Resource Type | ST Labor Workload | PM Labor Workload | CM Labor Workload | Other Support | ST Labor Workload | PM Labor Workload | CM Labor Workload | Other Support | ST Labor Workload | PM Labor Workload | CM Labor Workload | Other Support | ST Labor Workload | PM Labor Workload | CM Labor Workload | Other Support | Syst 042 | Rounds | | ST Labor Workload | PM Labor Workload | ST Labor Workload | PM Labor Workload | ST Labor Workload | PM Labor Workload | ST Labor Workload | PM Labor Workload | | |
| MA | I&C | Supervisor | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | | Craft | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | | Clerical | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | Electrical | Supervisor | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | | Craft | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | | Clerical | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | Mechanical | Craft | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | Support | Craft | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | CMO | Technician | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | Reactor Services | Technician | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | Maint Prep | Supervisor | 26 | - | - | - | - | - | - | - | 76 | - | - | - | 86 | - | - | - | - | 183 | **371** | 1 | - | - | - | 2 | - | 1 | - | **4** | **375** |
| | | Scheduler | 105 | - | 1 | - | - | - | 7 | - | 329 | - | 5 | - | 372 | - | 9 | - | 6 | - | **835** | - | 10 | - | 3 | - | 5 | - | 1 | **18** | **854** |
| | | Clerical | 22 | - | - | - | - | - | - | - | 76 | - | - | - | 86 | - | - | - | - | 219 | **403** | 1 | - | - | - | 2 | - | 1 | - | **4** | **407** |
| WM | Maint Prep | Planner | 89 | - | 3 | - | - | - | 21 | - | 329 | - | 12 | - | 372 | - | 19 | - | 12 | - | **858** | - | 18 | - | - | - | 17 | - | 10 | **45** | **903** |
| | Outage Mgmt | Scheduler | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 41 | - | - | - | 48 | - | 69 | - | **158** | **158** |
| | | Planner | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 29 | - | - | - | 31 | - | 48 | - | **107** | **107** |
| OP | Shift Ops | SRO | 14 | - | 0 | - | - | - | 2 | - | 76 | - | 1 | - | 94 | - | 2 | - | 2 | 511 | **702** | 1 | 5 | - | - | 2 | 8 | 1 | 1 | **18** | **720** |
| | | RO | 129 | - | 1 | - | - | - | 13 | - | 108 | - | 5 | - | 132 | - | 14 | - | 7 | 365 | **775** | 6 | 11 | - | - | 47 | 35 | 79 | 8 | **187** | **962** |
| | | EO | 60 | - | - | - | - | - | 3 | - | 64 | - | - | - | 20 | - | - | - | 4 | 2,920 | **3,071** | 32 | - | - | - | 58 | 43 | 58 | 3 | **195** | **3,266** |
| | Support | Scheduler | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | Services | Planner | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | | Clerical | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | Reactor Eng | Engineer | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| EN | Syst Eng | Supervisor | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | | Engineer | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| RP | Support | Technician | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| CY | Chemistry | Technician | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| CA | CAP | Various | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| TR | Ops | Various | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| | Maint | Various | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| IT | IT | Analyst | | | | | | | | | | | | | | | | | | | - | | | | | | | | | - | - |
| **TOTAL Number of Annual Hours:** | | | 445 | 0 | 6 | 0 | 0 | 0 | 46 | 0 | 1,059 | 0 | 24 | 0 | 1,163 | 0 | 45 | 0 | 31 | 4,198 | | 111 | 44 | 0 | 3 | 189 | 108 | 257 | 23 | | |
| | | | | | | **451** | | | | **46** | | | | **1,082** | | | | **1,208** | | **4,229** | **7,015** | | **155** | | **3** | | **298** | | **280** | **736** | **7,750** |
| | | | | | | | | | | | | | | | | | | | | | OK | | | | | | | | | OK | OK |

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**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 2.11**

**FTE Harvestability Worksheet**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

**PART I. FRACTIONAL FTE**

| Labor Division | | | Exclude Outage Workload? (Yes/No) | Workload Reduction (Hrs.) | Effective Hrs. per FTE | Potential Harvestable Resource? | Fractional Harvestable FTE | Comments |
|---|---|---|---|---|---|---|---|---|
| Functional Area | Work Group | Resource Type | | | | | | |
| MA | I&C | Supervisor | Yes | - | | | | |
| | | Craft | Yes | - | | | | |
| | | Clerical | Yes | - | | | | |
| | Electrical | Supervisor | Yes | - | | | | |
| | | Craft | Yes | - | | | | |
| | | Clerical | Yes | - | | | | |
| | Mechanical | Craft | Yes | - | | | | |
| | Support | Craft | Yes | - | | | | |
| | CMO | Technician | Yes | - | | | | |
| | Reactor Services | Technician | No | - | | | | |
| | Maint Prep | Supervisor | No | 375 | 1,700 | No | 0.220 | |
| | | Scheduler | No | 854 | 1,700 | No | 0.502 | Combine Scheduler/Planner and redistribute work |
| | | Clerical | No | 407 | 2,000 | No | 0.204 | |
| WM | Maint Prep | Planner | No | 903 | 1,700 | No | 0.531 | |
| | Outage Mgmt | Scheduler | No | 158 | 1,700 | No | 0.093 | |
| | | Planner | No | 107 | 1,700 | No | 0.063 | |
| OP | Shift Ops | SRO | No | 720 | 1,400 | No | 0.514 | |
| | | RO | No | 962 | 1,400 | No | 0.687 | |
| | | EO | No | 3,266 | 1,400 | Yes | 2.333 | Reassign Chemistry Operator tasks to Ops |
| | Support | Scheduler | No | - | | | | |
| | Services | Planner | No | - | | | | |
| | | Clerical | No | - | | | | |
| | Reactor Eng | Engineer | No | - | | | | |
| EN | Syst Eng | Supervisor | No | - | | | | |
| | | Engineer | No | - | | | | |
| RP | Support | Technician | No | - | | | | |
| CY | Chemistry | Technician | No | - | | | | |
| CA | CAP | Various | No | - | | | | |
| TR | Ops | Various | No | - | | | | |
| | Maint | Various | No | - | | | | |
| IT | MI | Analyst | No | - | | | | |

**PART II. CONSOLIDATED RESOURCES AND POTENTIAL FTE REDUCTIONS**

| Resource Description | | Total Workload Reduction (Hrs.) | Effective Hrs. per FTE | Potential Harvestable Resource? | Potential Harvestable FTE (Whole) | Comments |
|---|---|---|---|---|---|---|
| Chemistry | | 4,227 | 1,400 | Yes | 3.0 | |
| Scheduler/Planner (Maint Prep & Outage Mgt) | | 1,757 | 1,700 | Yes | 1.0 | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| **TOTAL FTE** | | | | | **4.0** | |

## Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations

**Appendix B - Sheet 3.1**

**Materials Estimate Worksheet (1 Sheet per System)**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

**System 1 Materials Estimate Worksheet**

| Catalog Item Description | CATID No. | Unit Price | Unit Price Year | Allocation to System | Current Unit Price | Qty in Inventory | Current Value of Inventory | Qty Purchased (5-Year) | Estimated Annual Expenditure | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Agastat Relay | 0011411708 | $ 445 | 2017 | 100% | $ 530 | 56 | $ 29,693 | 119 | $ 10,974 | |
| Contactor | 0011498631 | $ 579 | 2017 | 30% | $ 689 | 150 | $ 31,019 | 478 | $ 17,191 | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| | | | | | $ - | | $ - | | $ - | |
| Current Year: | | 2020 | | | | Total: | $ 60,713 | Total: | $ 28,165 | |
| Weighted Average Component Unit Cost CAGR: | | 6.0% | | | | | | | | |

**System 1 Materials Estimate Summary Table**

| | | | |
|---|---|---|---|
| **Estimated Annual Cost of Materials** | **$ 30,418** | | |
| Total Estimated Annual Expenditure of Mat'ls | $ 28,165 | | |
| Misc., Sundry and Consumable Items | $ 2,253 | 8% | of Annual Expenditure |

| | | | |
|---|---|---|---|
| **Estimated Carrying Cost of Materials** | **$ 6,071** | | |
| Annual Depreciation | | 20 | years (not applicable) |
| Supply Chain and Warehousing Charges | | 0.0% | (not applicable) |
| Capital Carrying Cost of Inventory | $ 6,071 | 10.0% | Cost of Capital |
| Property Taxes | | 0.0% | (not applicable) |
| Insurance | | 0.0% | (not applicable) |

| | |
|---|---|
| **Estimated Total Annual Cost Materials** | **$ 36,489** |

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 3.2**

**Material Expenditure Escalation Rate Worksheet (1 Sheet per System)**

**System 1**

| Year | Total Material Expenditure | 3-Year Moving Average Material Expenditure |
|---|---|---|
| 2002 | $9,489 | |
| 2003 | $58,850 | |
| 2004 | $30,000 | $32,780 |
| 2005 | $42,709 | $43,853 |
| 2006 | $70,668 | $47,792 |
| 2007 | $16,250 | $43,209 |
| 2008 | $71,871 | $52,930 |
| 2009 | $57,762 | $48,628 |
| 2010 | $39,850 | $56,494 |
| 2011 | $90,700 | $62,771 |
| 2012 | $56,455 | $62,335 |
| 2013 | $236,631 | $127,929 |
| 2014 | $149,896 | $147,661 |
| 2015 | $157,200 | $181,242 |
| 2016 | $92,662 | $133,253 |
| 2017 | $185,838 | $145,233 |
| 2018 | $246,937 | $175,146 |
| 2019 | $483,832 | $305,536 |

| Mat'l 3-Year Ave. Compound Annual Growth Rate | | |
|---|---|---|
| | Year | Expenditure |
| Start | 2004 | $32,780 |
| End | 2019 | $305,536 |
| | **CAGR** | **16%** |

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

## Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations

**Appendix B - Sheet 3.3**

**PART I. Weighted Average Component Unit Cost Escalation Worksheet (1 Sheet per System)**

| Sample No. | Cat ID | Component Description | Latest Price | 5-Yr Qty Purchased | Weight (Price x Qty) | CAGR |
|---|---|---|---|---|---|---|
| 1 | 11437163 | Power Supply | $ 7,500.00 | 2 | 15,000 | 13.8% |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
| | | | | | Weighted Average CAGR | 13.8% |

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND

**Part II. Sample Data for Standard Escalation Rate Analysis:**

**Sample 1**

| Component Name | CAT_ID | Qty Used Since 2003 |
|---|---|---|
| SUPPLY, POWER, 115 VAC/60 HZ INPUT, | 11437163 | |
| | | |

**Purchasing Data**

| PO | PO Date | Unit Price | Qty Purchased | Notes (e.g., Cat ID) |
|---|---|---|---|---|
| 523841 | 2/8/2019 | $7,500.00 | 1 | |
| 90089992 | 11/1/2017 | $5,000.00 | 1 | |
| 90060100 | 4/22/2013 | $3,595.00 | 1 | |
| 90056836 | 11/12/2012 | $3,270.00 | 1 | |
| 90033651 | 9/25/2009 | $1,800.00 | 1 | |
| 90033651 | 9/25/2009 | $1,800.00 | 1 | |
| 90013785 | 3/13/2005 | $1,221.00 | 1 | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| Year | Price |
|---|---|
| 2005 | $1,221.00 |
| 2019 | $7,500.00 |
| **CAGR** | **13.8%** |

**Sample X (Add samples as necessary)**

| Component Name | CAT_ID | Qty Used Since 2003 |
|---|---|---|
| | | |
| | | |

**Purchasing Data**

| PO | PO Date | Unit Price | Qty Purchased | Notes (e.g., Cat ID) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
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| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| Year | Price |
|---|---|
| | |
| | |
| | |

## Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations

**Appendix B - Sheet 4.1**

**Annual Labor and Materials Benefit Summary**

| $/FTE |
|---|
| 150,000 |

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

| LABOR | System 1 | System 2 | System 3 | System 4 | Common | Total |
|---|---|---|---|---|---|---|
| ***Workload Reduction*** | | | | | | |
| Online Workload Reduction (Resource-Hrs.) | | 1,610 | | | | 1,610 |
| Outage Workload Reduction (Resource-Hrs.) | | 89 | | | | 89 |
| *Total Workload Reduction (Hrs.)* | | *1,699* | | | | *1,699* |
| ***Harvestable FTE*** | | | | | | |
| Harvestable Labor (FTE) - Resource 1 | | 2 | | | | 2 |
| Harvestable Labor (FTE) - Resource 2 | | -- | | | | 0 |
| Harvestable Labor (FTE) - Resource 3 | | 3 | | | | 3 |
| *Total Harvestable Labor (FTE)* | | *5* | | | | *5* |
| ***Annual Monetary Benefit ($ 2020)*** | | | | | | |
| Harvestable Labor Benefit ($) | 0 | 750,000 | 0 | 0 | 0 | 750,000 |
| Contract Labor ($) | | 152,390 | | | | 152,390 |
| Overtime ($) | | 4,672 | | | | 4,672 |
| **TOTAL ANNUAL LABOR BENEFIT** | **0** | **907,062** | **0** | **0** | **0** | **907,062** |

| MATERIALS AND TOOLS | System 1 | System 2 | System 3 | System 4 | Common | Total |
|---|---|---|---|---|---|---|
| ***Estimate Basis*** | | | | | | |
| Current Value of Inventory | | 3,000,000 | | | | 3,000,000 |
| Escalation Rate | | 18% | | | | n/a |
| ***Annual Cost of Materials*** | | | | | | |
| Annual Purchases of Materials | | 400,000 | | | | 400,000 |
| Misc. Sundry and Consumable Items | | 9,000 | | | | 9,000 |
| Carrying Cost | | 300,000 | | | | 300,000 |
| **TOTAL ANNUAL MATERIALS BENEFIT** | **0** | **709,000** | **0** | **0** | **0** | **709,000** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **TOTAL ANNUAL BENEFIT** | **0** | **1,616,062** | **0** | **0** | **-** | **1,616,062** |

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**

**Appendix B - Sheet 4.2**

**Project Capital and Ongoing Operating Cost Summary**

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

| | | |
|---|---|---|
| Current Year (Year 0) | 2020 | |
| Project Lifecycle | 20 | years |

| Project Installed and Ongoing Costs | | | | | Year | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| System (Unit) | Installed Cost (thousands) | Ongoing O&M Cost (thousands) | Escalation of Labor and Materials | Year Cost Initiated | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 |
| **One Time Project Costs (thousands)** | | | | | | | | | | | | | | | | | | | | |
| Project Development | $ 4,000 | | | | 4,000 | | | | | | | | | | | | | | | |
| Engineering | $ 18,000 | | | | 5,000 | 8,000 | 5,000 | | | | | | | | | | | | | |
| Equipment | $ 23,000 | | | | | | 9,000 | 7,000 | 4,000 | 3,000 | | | | | | | | | | |
| Construction | $ 18,000 | | | | | | 4,000 | 6,000 | 6,000 | 2,000 | | | | | | | | | | |
| Other | $ (500) | | | | | | | | (250) | | (250) | | | | | | | | | |
| | $ - | | | | | | | | | | | | | | | | | | | |
| **Ongoing Operating and Maintenance Cost** | | | | | | | | | | | | | | | | | | | | |
| Unit 1 PPS | | $ 25.00 | 4% | 2023 | - | - | - | 28 | 29 | 30 | 32 | 33 | 34 | 36 | 37 | 38 | 40 | 42 | 43 | 45 |
| Unit 2 DAS/DCS | | $ 12.00 | 4% | 2023 | - | - | - | 13 | 14 | 15 | 15 | 16 | 16 | 17 | 18 | 18 | 19 | 20 | 21 | 22 |
| Unit 1 Other | | $ 6.00 | 4% | 2023 | - | - | - | 7 | 7 | 7 | 8 | 8 | 8 | 9 | 9 | 9 | 10 | 10 | 10 | 11 |
| Unit 2 PPS | | $ 25.00 | 4% | 2025 | - | - | - | - | - | 30 | 32 | 33 | 34 | 36 | 37 | 38 | 40 | 42 | 43 | 45 |
| Unit 2 DAS/DCS | | $ 12.00 | 4% | 2025 | - | - | - | - | - | 15 | 15 | 16 | 16 | 17 | 18 | 18 | 19 | 20 | 21 | 22 |
| Unit 2 Other | | $ 6.00 | 4% | 2025 | - | - | - | - | - | 7 | 8 | 8 | 8 | 9 | 9 | 9 | 10 | 10 | 10 | 11 |
| | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Total Cost** | **62,500** | **$ 86.00** | | **Nominal Cash Flows:** | **9,000** | **8,000** | **18,000** | **13,048** | **9,800** | **5,105** | **(141)** | **113** | **118** | **122** | **127** | **132** | **138** | **143** | **149** | **155** |

| | Year | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| System (Unit) | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 |
| **One Time Project Costs (thousands)** | | | | | | | | | | | | | | | |
| Project Development | | | | | | | | | | | | | | | |
| Engineering | | | | | | | | | | | | | | | |
| Equipment | | | | | | | | | | | | | | | |
| Construction | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **Ongoing Operating and Maintenance Cost** | | | | | | | | | | | | | | | |
| Unit 1 PPS | 47 | 49 | 51 | 53 | 55 | 57 | 59 | - | - | - | - | - | - | - | - |
| Unit 2 DAS/DCS | 22 | 23 | 24 | 25 | 26 | 27 | 28 | - | - | - | - | - | - | - | - |
| Unit 1 Other | 11 | 12 | 12 | 13 | 13 | 14 | 14 | - | - | - | - | - | - | - | - |
| Unit 2 PPS | 47 | 49 | 51 | 53 | 55 | 57 | 59 | 62 | 64 | - | - | - | - | - | - |
| Unit 2 DAS/DCS | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 30 | 31 | - | - | - | - | - | - |
| Unit 2 Other | 11 | 12 | 12 | 13 | 13 | 14 | 14 | 15 | 15 | - | - | - | - | - | - |
| | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Total Cost** | **161** | **168** | **174** | **181** | **188** | **196** | **204** | **106** | **110** | **-** | **-** | **-** | **-** | **-** | **-** |

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**
**Appendix B - Sheet 4.3**
**Project Financial Analysis Worksheet**

## PART I. GENERAL

| | | |
|---|---|---|
| Current Year (Year 0) | 2020 | |
| Project Lifecycle | 25 | years |
| Owner Cost of Capital | 10% | |

**SUMMARY FINANCIALS**

| | | |
|---|---|---|
| NPV | $65.94 | million |
| IRR | 17.37 | % |
| PAYBACK | 11 | years |

SAMPLE FIGURES PROVIDED IN THIS TEMPLATE ARE FOR ILLUSTRATIVE PURPOSES ONLY AND ARE NOT INTENDED TO REPRESENT ACTUAL PROJECT DATA.

## PART II. LABOR BENEFITS

### A) Harvestable FTE

| | | |
|---|---|---|
| Current Annual Cost of FTE: | 150 | thousand |
| Labor Escalation Rate: | 3% | |

| Present Value of Harvestable Labor (FTE) | | | | Year | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| **Direct Labor Benefit Trigger** | **No. of FTE** | **Labor Escalation Rate** | **Year Benefit Available** | **2020** | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031** | **2032** | **2033** | **2034** | **2035** | **2036** | **2037** | **2038** | **2039** | **2040** | **2041** | **2042** | **2043** | **2044** | **2045** | **2046** | **2047** | **2048** | **2049** | **2050** |
| Unit 1 Part I Complete | 1 | 3% | 2022 | - | - | 159 | 164 | 169 | 174 | 179 | 184 | 190 | 196 | 202 | 208 | 214 | 220 | 227 | 234 | 241 | 248 | 255 | 263 | 271 | 279 | 287 | 296 | 305 | 314 | 323 | - | - | - | - |
| Unit 2 Part I Complete | 2 | 3% | 2023 | - | - | - | 328 | 338 | 348 | 358 | 369 | 380 | 391 | 403 | 415 | 428 | 441 | 454 | 467 | 481 | 496 | 511 | 526 | 542 | 558 | 575 | 592 | 610 | 628 | 647 | 666 | - | - | - |
| Unit 1 Part II Complete | 1 | 3% | 2024 | - | - | - | - | 169 | 174 | 179 | 184 | 190 | 196 | 202 | 208 | 214 | 220 | 227 | 234 | 241 | 248 | 255 | 263 | 271 | 279 | 287 | 296 | 305 | 314 | 323 | 333 | 343 | - | - |
| Unit 2 Part II Complete | 4 | 3% | 2025 | - | - | - | - | - | 696 | 716 | 738 | 760 | 783 | 806 | 831 | 855 | 881 | 908 | 935 | 963 | 992 | 1,021 | 1,052 | 1,084 | 1,116 | 1,150 | 1,184 | 1,220 | 1,256 | 1,294 | 1,333 | 1,373 | 1,414 | - |
| | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Cash Flow (Labor FTE)** | | | | **-** | **-** | **159** | **492** | **675** | **1,391** | **1,433** | **1,476** | **1,520** | **1,566** | **1,613** | **1,661** | **1,711** | **1,762** | **1,815** | **1,870** | **1,926** | **1,983** | **2,043** | **2,104** | **2,167** | **2,232** | **2,299** | **2,368** | **2,439** | **2,513** | **2,588** | **2,332** | **1,716** | **1,414** | **-** |
| **Discounted Cash Flow (Labor FTE)** | | | | **-** | **-** | **132** | **369** | **461** | **864** | **809** | **757** | **709** | **664** | **622** | **582** | **545** | **510** | **478** | **448** | **419** | **392** | **367** | **344** | **322** | **302** | **282** | **264** | **248** | **232** | **217** | **178** | **119** | **89** | **-** |

**Present Value (Direct Labor)** **$11.73 million**

### B) Other Labor

| Present Value of Other Labor Categories | | | | Year | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| **Labor Category** | **Annual Benefit (thousands)** | **Labor Escalation Rate** | **Year Benefit Available** | **2020** | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031** | **2032** | **2033** | **2034** | **2035** | **2036** | **2037** | **2038** | **2039** | **2040** | **2041** | **2042** | **2043** | **2044** | **2045** | **2046** | **2047** | **2048** | **2049** | **2050** |
| Contract Labor (Unit 1) | $ 550.00 | 3% | 2024 | - | - | - | - | 619 | 638 | 657 | 676 | 697 | 718 | 739 | 761 | 784 | 808 | 832 | 857 | 883 | 909 | 936 | 964 | 993 | 1,023 | 1,054 | 1,085 | 1,118 | 1,152 | 1,186 | 1,222 | 1,258 | - | - |
| Contract Labor (Unit 2) | $ 550.00 | 3% | 2025 | - | - | - | - | - | 638 | 657 | 676 | 697 | 718 | 739 | 761 | 784 | 808 | 832 | 857 | 883 | 909 | 936 | 964 | 993 | 1,023 | 1,054 | 1,085 | 1,118 | 1,152 | 1,186 | 1,222 | 1,258 | 1,296 | - |
| Overtime | $ 80.00 | 3% | 2025 | - | - | - | - | - | 93 | 96 | 98 | 101 | 104 | 108 | 111 | 114 | 117 | 121 | 125 | 128 | 132 | 136 | 140 | 144 | 149 | 153 | 158 | 163 | 168 | 173 | 178 | 183 | 189 | - |
| | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Cash Flow (Other Labor)** | | | | **-** | **-** | **-** | **-** | **619** | **1,368** | **1,409** | **1,451** | **1,495** | **1,540** | **1,586** | **1,633** | **1,682** | **1,733** | **1,785** | **1,838** | **1,894** | **1,950** | **2,009** | **2,069** | **2,131** | **2,195** | **2,261** | **2,329** | **2,399** | **2,471** | **2,545** | **2,621** | **2,700** | **1,485** | **-** |
| **Discounted Cash Flow (Other Labor)** | | | | **-** | **-** | **-** | **-** | **423** | **849** | **795** | **745** | **697** | **653** | **611** | **572** | **536** | **502** | **470** | **440** | **412** | **386** | **361** | **338** | **317** | **297** | **278** | **260** | **244** | **228** | **214** | **200** | **187** | **94** | **-** |

**Present Value (Other Labor)** **$ 11.11 million**

## PART III. MATERIAL BENEFITS

### A. Annual Material Expenditures

| Present Value of Material Expenditures | | | | Year | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| **System (Unit)** | **Annual Benefit (thousands)** | **Mat'l Escalation Rate** | **Year Benefit Available** | **2020** | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031** | **2032** | **2033** | **2034** | **2035** | **2036** | **2037** | **2038** | **2039** | **2040** | **2041** | **2042** | **2043** | **2044** | **2045** | **2046** | **2047** | **2048** | **2049** | **2050** |
| **Unit 1** | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 1 | $ 324.00 | 18% | 2022 | - | - | 451 | 532 | 628 | 741 | 875 | 1,032 | 1,218 | 1,437 | 1,696 | 2,001 | 2,361 | 2,786 | 3,288 | 3,879 | 4,578 | 5,402 | 6,374 | 7,521 | 8,875 | 10,473 | 12,358 | 14,582 | 17,207 | 20,305 | 23,959 | - | - | - | - |
| System 2 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 3 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 4 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Common | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Unit 2** | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 1 | $ 324.00 | 18% | 2023 | - | - | - | 532 | 628 | 741 | 875 | 1,032 | 1,218 | 1,437 | 1,696 | 2,001 | 2,361 | 2,786 | 3,288 | 3,879 | 4,578 | 5,402 | 6,374 | 7,521 | 8,875 | 10,473 | 12,358 | 14,582 | 17,207 | 20,305 | 23,959 | 28,272 | - | - | - |
| System 2 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 3 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 4 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Common | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Cash Flow (Materials)** | | | | **-** | **-** | **451** | **1,065** | **1,256** | **1,482** | **1,749** | **2,064** | **2,436** | **2,874** | **3,392** | **4,002** | **4,722** | **5,572** | **6,575** | **7,759** | **9,156** | **10,804** | **12,748** | **15,043** | **17,751** | **20,946** | **24,716** | **29,165** | **34,415** | **40,609** | **47,919** | **28,272** | **-** | **-** | **-** |
| **Discounted Cash Flow (Materials)** | | | | **-** | **-** | **373** | **800** | **858** | **920** | **987** | **1,059** | **1,136** | **1,219** | **1,308** | **1,403** | **1,505** | **1,614** | **1,732** | **1,857** | **1,993** | **2,137** | **2,293** | **2,460** | **2,639** | **2,830** | **3,036** | **3,257** | **3,494** | **3,748** | **4,021** | **2,157** | **-** | **-** | **-** |

**Present Value (Materials)** **$ 50.84 million**

### B. Inventory Carrying Cost

| Present Value of Inventory Carrying Cost | | | | Year | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| **System (Unit)** | **Annual Benefit (thousands)** | **Component Unit Cost Escalation** | **Year Benefit Available** | **2020** | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031** | **2032** | **2033** | **2034** | **2035** | **2036** | **2037** | **2038** | **2039** | **2040** | **2041** | **2042** | **2043** | **2044** | **2045** | **2046** | **2047** | **2048** | **2049** | **2050** |
| **Unit 1** | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 1 | 433 | 15% | 2022 | - | - | 573 | 659 | 757 | 871 | 1,002 | 1,152 | 1,325 | 1,523 | 1,752 | 2,014 | 2,317 | 2,664 | 3,064 | 3,523 | 4,052 | 4,660 | 5,359 | 6,162 | 7,087 | 8,150 | 9,372 | 10,778 | 12,395 | 14,254 | 16,392 | - | - | - | - |
| System 2 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 3 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 4 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Common | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Unit 2** | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 1 | 433 | 15% | 2023 | - | - | - | 659 | 757 | 871 | 1,002 | 1,152 | 1,325 | 1,523 | 1,752 | 2,014 | 2,317 | 2,664 | 3,064 | 3,523 | 4,052 | 4,660 | 5,359 | 6,162 | 7,087 | 8,150 | 9,372 | 10,778 | 12,395 | 14,254 | 16,392 | 18,851 | - | - | - |
| System 2 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 3 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| System 4 | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Common | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Cash Flow (Inventory)** | | | | **-** | **-** | **573** | **1,317** | **1,515** | **1,742** | **2,003** | **2,304** | **2,649** | **3,046** | **3,503** | **4,029** | **4,633** | **5,328** | **6,128** | **7,047** | **8,104** | **9,319** | **10,717** | **12,325** | **14,173** | **16,299** | **18,744** | **21,556** | **24,789** | **28,508** | **32,784** | **18,851** | **-** | **-** | **-** |
| **Discounted Cash Flow (Inventory)** | | | | **-** | **-** | **473** | **990** | **1,035** | **1,082** | **1,131** | **1,182** | **1,236** | **1,292** | **1,351** | **1,412** | **1,476** | **1,543** | **1,614** | **1,687** | **1,764** | **1,844** | **1,928** | **2,015** | **2,107** | **2,203** | **2,303** | **2,407** | **2,517** | **2,631** | **2,751** | **1,438** | **-** | **-** | **-** |

**Present Value (Inventory)** **$43.41 million**

**Business Case Analysis for Digital Safety Related Instrumentation & Control System Modernizations**
**Appendix B - Sheet 4.3**
**Project Financial Analysis Worksheet**

## PART IV. PROJECT COSTS

Present Value of Project Costs (Year 0–14)

| System (Unit) | Annual Cost (thousands) | Escalation of Labor and Materials | Year Cost Initiated | 0<br>2020 | 1<br>2021 | 2<br>2022 | 3<br>2023 | 4<br>2024 | 5<br>2025 | 6<br>2026 | 7<br>2027 | 8<br>2028 | 9<br>2029 | 10<br>2030 | 11<br>2031 | 12<br>2032 | 13<br>2033 | 14<br>2034 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **One Time Project Costs (thousands)** | | | | | | | | | | | | | | | | | | |
| Project Development | | | | 4,000 | | | | | | | | | | | | | | |
| Engineering | | | | 5,000 | 8,000 | 5,000 | | | | | | | | | | | | |
| Equipment | | | | | | 9,000 | 7,000 | 4,000 | 3,000 | | | | | | | | | |
| Construction | | | | | | 4,000 | 6,000 | 6,000 | 2,000 | | | | | | | | | |
| Other | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| **Ongoing Operating and Maintenance** | | | | | | | | | | | | | | | | | | |
| Unit 1 PPS | $ 25.00 | 4% | 2023 | - | - | - | 28 | 29 | 30 | 32 | 33 | 34 | 36 | 37 | 38 | 40 | 42 | 43 |
| Unit 2 DAS/DCS | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Unit 1 Other | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Unit 2 PPS | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Unit 2 DAS/DCS | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Unit 2 Other | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Cash Flow (Installed Costs)** | | | | (9,000) | (8,000) | (18,000) | (13,028) | (10,029) | (5,030) | (32) | (33) | (34) | (36) | (37) | (38) | (40) | (42) | (43) |
| **Discounted Cash Flow (Installed Costs)** | | | | (9,000) | (7,273) | (14,876) | (9,788) | (6,850) | (3,123) | (18) | (17) | (16) | (15) | (14) | (13) | (13) | (12) | (11) |

Year (15–30)

| System (Unit) | 15<br>2035 | 16<br>2036 | 17<br>2037 | 18<br>2038 | 19<br>2039 | 20<br>2040 | 21<br>2041 | 22<br>2042 | 23<br>2043 | 24<br>2044 | 25<br>2045 | 26<br>2046 | 27<br>2047 | 28<br>2048 | 29<br>2049 | 30<br>2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **One Time Project Costs (thousands)** | | | | | | | | | | | | | | | | |
| Project Development | | | | | | | | | | | | | | | | |
| Engineering | | | | | | | | | | | | | | | | |
| Equipment | | | | | | | | | | | | | | | | |
| Construction | | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| **Ongoing Operating and Maintenance** | | | | | | | | | | | | | | | | |
| Unit 1 PPS | 45 | 47 | 49 | 51 | 53 | 55 | 57 | 59 | 62 | 64 | 67 | 69 | 72 | - | - | - |
| Unit 2 DAS/DCS | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Unit 1 Other | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Unit 2 PPS | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Unit 2 DAS/DCS | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Unit 2 Other | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Cash Flow (Installed Costs)** | (45) | (47) | (49) | (51) | (53) | (55) | (57) | (59) | (62) | (64) | (67) | (69) | (72) | - | - | - |
| **Discounted Cash Flow (Installed Costs)** | (11) | (10) | (10) | (9) | (9) | (8) | (8) | (7) | (7) | (7) | (6) | (6) | (5) | - | - | - |

**Present Value (Installed Costs)** **($51.14) million**

## PART V. NET PRESENT VALUE

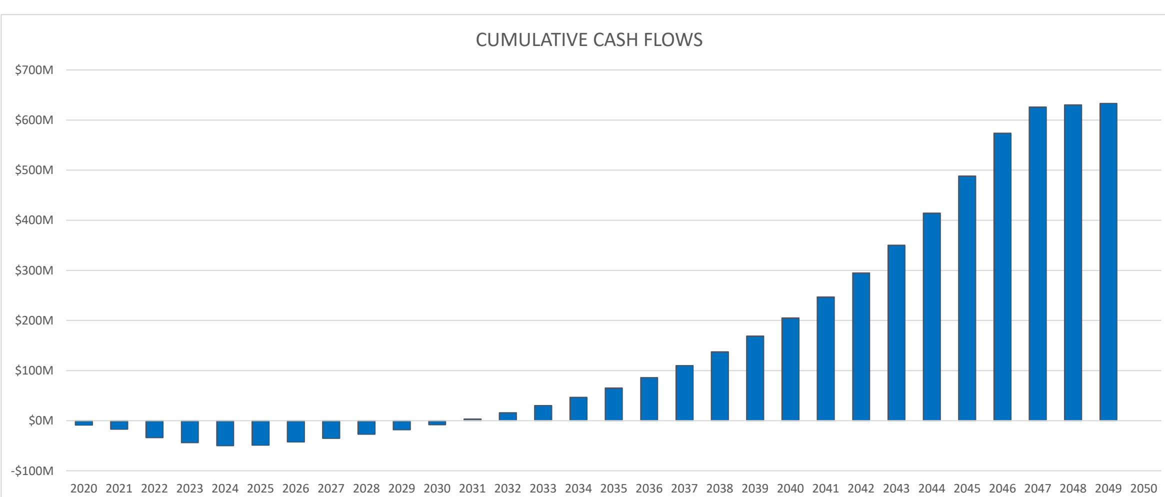
| | | |
|---|---|---|
| Present Value (Direct Labor) | $ 11.73 | |
| Present Value (Other Labor) | $ 11.11 | |
| Present Value (Materials) | $ 50.84 | |
| Present Value (Inventory) | $ 43.41 | |
| Present Value (Installed Costs) | $ (51.14) | |
| **NET PRESENT VALUE (PROJECT)** | **$ 65.94** | **million** |

## PART VI. INTERNAL RATE OF RETURN AND PAYBACK PERIOD

| Cash Flow (thousands) | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cash Flow (Labor FTE) | - | - | 159 | 492 | 675 | 1,391 | 1,433 | 1,476 | 1,520 | 1,566 | 1,613 | 1,661 | 1,711 | 1,762 | 1,815 |
| Cash Flow (Other Labor) | - | - | - | - | 619 | 1,368 | 1,409 | 1,451 | 1,495 | 1,540 | 1,586 | 1,633 | 1,682 | 1,733 | 1,785 |
| Cash Flow (Materials) | - | - | 451 | 1,065 | 1,256 | 1,482 | 1,749 | 2,064 | 2,436 | 2,874 | 3,392 | 4,002 | 4,722 | 5,572 | 6,575 |
| Cash Flow (Inventory) | - | - | 573 | 1,317 | 1,515 | 1,742 | 2,003 | 2,304 | 2,649 | 3,046 | 3,503 | 4,029 | 4,633 | 5,328 | 6,128 |
| Cash Flow (Installed Costs) | (9,000) | (8,000) | (18,000) | (13,028) | (10,029) | (5,030) | (32) | (33) | (34) | (36) | (37) | (38) | (40) | (42) | (43) |
| **Cash Flow (Total)** | **(9,000)** | **(8,000)** | **(16,817)** | **(10,155)** | **(5,964)** | **953** | **6,563** | **7,262** | **8,066** | **8,990** | **10,056** | **11,287** | **12,709** | **14,354** | **16,260** |
| **Cumulative Cash Flow (Total)** | **(9,000)** | **(17,000)** | **(33,817)** | **(43,972)** | **(49,936)** | **(48,983)** | **(42,420)** | **(35,158)** | **(27,093)** | **(18,102)** | **(8,046)** | **3,241** | **15,950** | **30,304** | **46,564** |
| **Payback Year** | | | | | | | | | | | | **2031** | | | |

| Cash Flow (thousands) | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cash Flow (Labor FTE) | 1,870 | 1,926 | 1,983 | 2,043 | 2,104 | 2,167 | 2,232 | 2,299 | 2,368 | 2,439 | 2,513 | 2,588 | 2,332 | 1,716 | 1,414 | - |
| Cash Flow (Other Labor) | 1,838 | 1,894 | 1,950 | 2,009 | 2,069 | 2,131 | 2,195 | 2,261 | 2,329 | 2,399 | 2,471 | 2,545 | 2,621 | 2,700 | 1,485 | - |
| Cash Flow (Materials) | 7,759 | 9,156 | 10,804 | 12,748 | 15,043 | 17,751 | 20,946 | 24,716 | 29,165 | 34,415 | 40,609 | 47,919 | 28,272 | - | - | - |
| Cash Flow (Inventory) | 7,047 | 8,104 | 9,319 | 10,717 | 12,325 | 14,173 | 16,299 | 18,744 | 21,556 | 24,789 | 28,508 | 32,784 | 18,851 | - | - | - |
| Cash Flow (Installed Costs) | (45) | (47) | (49) | (51) | (53) | (55) | (57) | (59) | (62) | (64) | (67) | (69) | (72) | - | - | - |
| **Cash Flow (Total)** | **18,469** | **21,032** | **24,008** | **27,467** | **31,488** | **36,168** | **41,616** | **47,961** | **55,356** | **63,978** | **74,034** | **85,766** | **52,004** | **4,416** | **2,899** | **-** |
| **Cumulative Cash Flow (Total)** | **65,033** | **86,064** | **110,072** | **137,539** | **169,027** | **205,195** | **246,811** | **294,772** | **350,129** | **414,107** | **488,141** | **573,907** | **625,911** | **630,327** | **633,225** | **-** |
| **Payback Year** | | | | | | | | | | | | | | | | |

| | | |
|---|---|---|
| **PAYBACK PERIOD** | **11** | **years** |
| **INTENRAL RATE OF RETURN (IRR)** | **17.37%** | |



# Appendix C: A Case Study in Component Obsolescence

# APPENDIX C:
# A CASE STUDY IN COMPONENT OBSOLESCENCE

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# FIGURES

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# 1. Introduction

Based on early interviews with plant staff, the project team investigated reports of high escalation of analog components in one of the systems. An analysis of purchasing history of system components revealed that material costs escalated for one of the safety related Instrumentation & Controls (I&C) systems at a compound annual growth rate (CAGR) of over 20 percent.

# 2. Labor and Material Trends

Continued growth of material costs for this system will make maintaining/supporting the existing system uneconomical. Although historical records indicate cost management efforts have reduced the annual cost of labor to maintain the system, growth in cost of materials offsets these gains, as illustrated in Figure C-1 below.

- Annual material expenditure increases are driven by both escalating component unit prices and increasing failure rates
- Replacement components are harder to find, resulting in more supply chain and engineering time spent trying to procure the parts
- Limited supplier base is one factor driving the high price of these components.

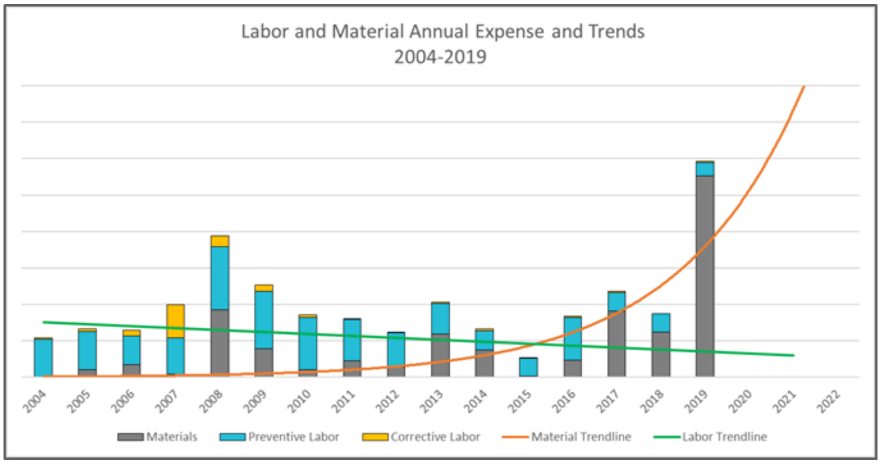


Figure C-1: Labor and material annual expense trends.

## 2.1 Escalation of Components

To investigate obsolescence in greater detail, the project team sampled procurement records of analog components (i.e., I/O cards) that made up 80–90% of annual material expenditures:

- Unit price growth rates were determined by fitting trendlines to historical purchase data of components
- Double-digit growth rates were demonstrated for many of the frequently exchanged components, and Figure C-2 below illustrates an observed growth rate of 30% of one such component between the years 2008 and 2019.

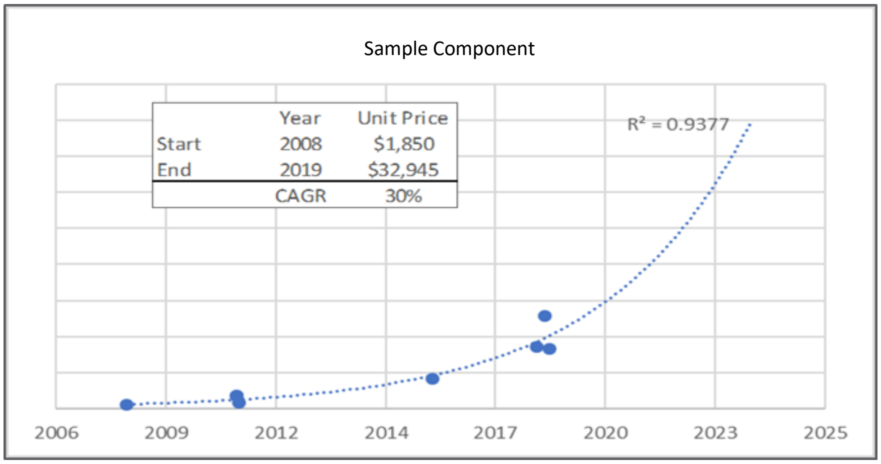


Figure C-2: CAGR of sample component.

Further analysis demonstrated that the average rate of escalation of system components was 15%, when weighted by the unit price of the component.

## 2.2 Escalation of Material Expenditures

While component escalation contributed significantly to annual material costs, the analysis at the component level did not fully explain the annual increases.

Further investigation indicated the reliability of system components is deteriorating. Due to the obsolescence of the integrated circuits on the cards, existing cards were being refurbished rather than being newly manufactured. Increased failure rates of the refurbished cards led to a need for more frequent maintenance on the system as well as increases in system-engineering time to troubleshoot system faults.

# 3. Valuation of Avoided Cost of Obsolescence

Given that component obsolescence is the driving force behind rapidly increasing system costs, replacement of this system with a modern system would mitigate this issue. To demonstrate the value of avoiding future system costs, the project team compared expected future costs with the current system and compared that to expected future costs if obsolescence were not a contributing factor. Comparing the present value of these two scenarios provides a picture of the avoided cost of obsolescence shown in Figure C-3 below.

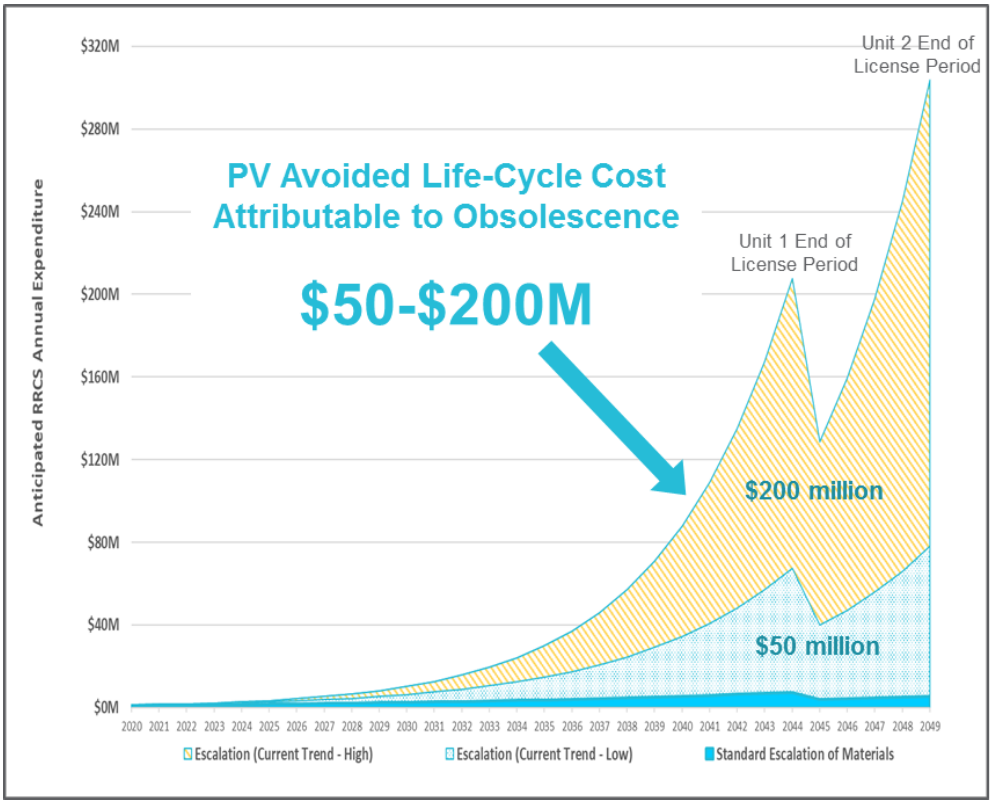


Figure C-3: Present value of avoided cost attributable to obsolescence.

An analysis estimates the present value of avoided cost attributable to obsolescence for material expenditures and reduced capital carrying costs enabled by replacing this system to be between $50 and $200 million. The present value was calculated as:

$$PV_{Avoided} = \sum_{n=First\ Year}^{Final\ Year} \frac{Material\ Expense \times \left[(1 + Rate_{Observed})^n - (1 + Rate_{Expected})^n\right]}{(1 + Cost\ of\ Capital)^n}$$

Where:

$$PV_{Avoided} = Present\ Value\ of\ Avoided\ Cost\ Attributable\ to\ Obsolescence$$

$$Annual\ Mat'l\ Expense = Current\ Average\ Annual\ Material\ Expenditure$$

$$Rate_{Observed} = Historical\ Escalation\ Rate\ Observed$$

$$Rate_{Expected} = Escalation\ Rate\ Expected\ (Typical)$$

$$Cost\ of\ Capital = Cost\ of\ Capital\ Provided\ by\ Owner$$

$$n = Nominal\ Year$$

$$First\ Year = Year\ in\ which\ cost\ if\ first\ avoided\ (i.e., after\ implementation\ is\ complete)$$

$$Final\ Year = Year\ project\ life\ cycle\ ends\ (defined\ by\ Project\ Team)$$

## 3.1 Key Inputs for Present Value

- Annual expenditure (in current dollars) was calculated using average system material expenditures over the most recent three-year period. To estimate the expected materials expenditures in future years, the project team created three growth scenarios determined by statistical analysis of purchase data.
- Three growth rate scenarios were analyzed to determine the impact of the materials CAGR on project present value:
    - A base scenario (expected) material escalation of 5%
    - A low scenario of escalation of approximately 15%
    - A high scenario of escalation of approximately 25%.

## 3.2 Present Value Analysis

Anticipated system expenditures under the three growth scenarios discounted to current dollars providing a present value dollar amount (graphically represented as the area under the curve in Figure C-3 above). When compared to the base scenario, the calculated value of Avoided Cost of Obsolescence is between $50 and $200 million in present terms.[1]

Based on the results of this case study, a similar methodology was applied to material expenditures of other systems. While growth rates of these systems did not approach double digits, they ranged from 6 to 9% and were higher than the expected 5% that would typically be used in financial analysis of project net present value. The team incorporated these growth rates into the business case financial analysis.

The analysis conducted to determine the true rate of escalation for these aging systems provided a methodology for an analyst to present the cost of obsolescence as an important factor in development of the business case analysis.

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[1] This analysis assumes that these components, whether new or refurbished will continue to be available through the end of the license period.

# Appendix D: Business Case Analysis (BCA) Presentation

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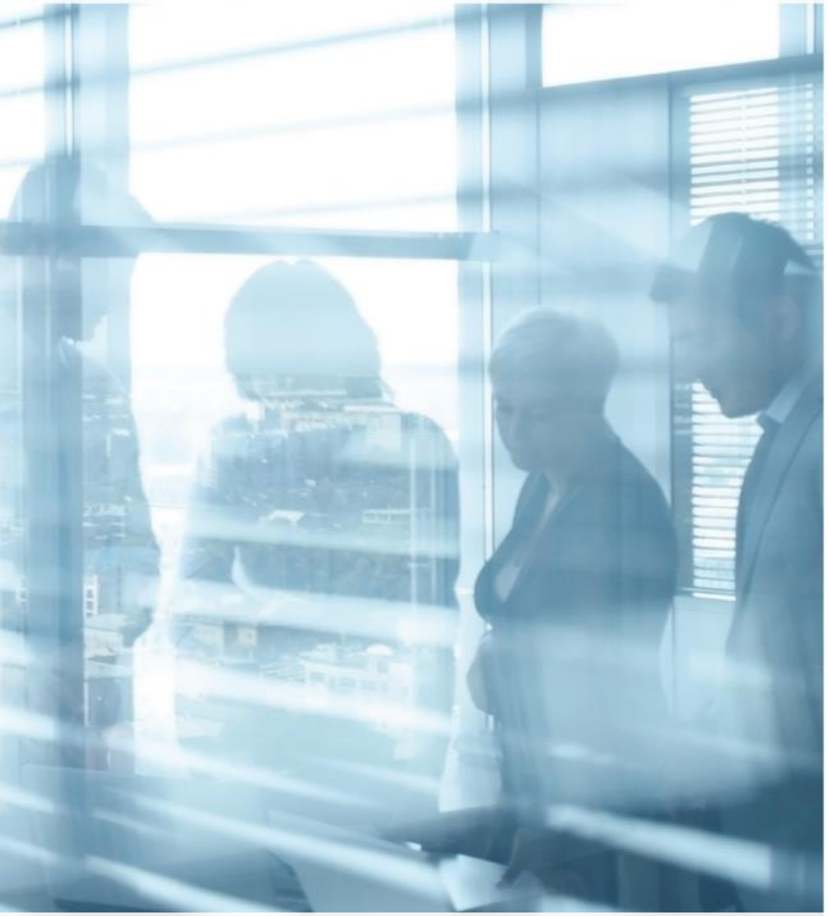

LWRS LIGHT WATER REACTOR SUSTAINABILITY

MPR

# Business Case Analysis (BCA) for Digital Safety Related Instrumentation & Control System Modernizations

Appendix D to INL/EXT-20-59371

August 2020

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# Project Overview

# Summary

- The commercial nuclear sector faces unprecedented financial challenge driven by low natural gas prices and subsidized renewables in a marketplace that does not reward carbon-free baseload capacity
  - These circumstances in concert with *an increasingly antiquated labor-centric operating model* have forced premature closure of multiple nuclear facilities and placed many more at risk
  - To enable nuclear plants to survive in current and forecasted market conditions, *a more efficient and technology-centric operating model* that harvests the native efficiencies of advanced technology is required
  - This is analogous to transformation that has occurred in nearly every other industry
- Though historical licensing barriers have largely precluded the modernization of nuclear plant first-echelon safety systems to support this transformation, these barriers have now been largely addressed through collaboration between industry leaders and the Nuclear Regulatory Commission (NRC)
  - These advances enable the modernization of key safety systems through the streamlined license amendment process reflected in Digital Instrumentation and Controls Interim Staff Guidance #06 (DI&C-ISG-06), Revision 2, "Licensing Process"
- While regulatory advances have improved the environment for modernizing safety systems, the industry has remained reluctant to perform such instrumentation and controls (I&C) upgrades because of perceived regulatory risks associated with being the first adopter of the DI&C-ISG-06, Revision 2 process for a major critical safety system
  - Light Water Reactor Sustainability Program (LWRS) research report INL/LTD-20-58490, *Vendor-Independent Design Requirements for a Boiling Water Reactor Safety System Upgrade*, was developed in part to help address this concern
- Nuclear utilities are reluctant to pursue these upgrades due to historical uncertainty in both cost and licensing
  - A nuclear station safety I&C system upgrade implemented in the 2000s took over 10 years to implement, and saw significant cost overruns
  - Although ultimately completed, this project resulted in widespread industry skepticism concerning the regulatory approval process and cost predictability for such upgrades

# LWRS Project Objectives

- Assist in breaking the impasse which has precluded digital safety system upgrades by generating and demonstrating a process and related business case tool to enable a Business Case Analysis (BCA)
- Justify upgrade economics and systematically establish a forecast of expected lifecycle costs for I&C by:
  - Definitively bounding the scope of current I&C systems envisioned for upgrade
  - Collecting historical labor and material usage data that bound cost contributors related to the systems to be upgraded
  - Synthesizing and analyzing the data to establish lifecycle cost forecasts for the current system
- Identify cost savings categories and expected savings and apply using the analysis tools developed for this purpose, resulting in an estimate Present Value (PV) of savings enabled by the upgrade
  - Include utility-provided digital upgrade costs estimates to generate a Net Present Value (NPV) for the upgrade project
- Use an Exelon-owned 2-Unit Boiling Water Reactor (BWR) Station (the “Station”) that is pursuing a digital upgrade of current, first-echelon, safety-related I&C systems as the foundation for this research. These systems include:
  - Reactor Protection System (RPS)
  - Nuclear Steam Supply Shutoff System (N4S)
  - Emergency Core Cooling Systems (ECCS)
  - Anticipated Transient Without Scram (ATWS) Mitigation System (ATWSMS)

# Approach

# Introduction

- Illustrate for utilities considering a digital modernization of I&C systems a methodology to evaluate cross-functional labor and material benefits
- Conduct a financial analysis to develop the overall business case
- Objectives includes:
  - Providing a “bottom-up” approach to:
    - Establish labor and material costs for the current systems
    - Identify expected labor and material benefits enabled by the upgrade design concept
    - Validate expected benefits with Subject Matter Experts (SMEs)
  - Demonstrating a methodology utilized to perform a detailed financial analysis, including:
    - Estimate annual benefits of organizational workload reductions for both online and outage work
    - Estimate annual benefits of materials and inventory expenditures
    - Valuation of avoided lifecycle costs associated with escalation of material expenditures
    - Valuation of the modernization over the lifecycle of the Station
  - Illustrating the scale of benefits expected from a modernization of safety-related I&C systems at a 2-Unit BWR nuclear power station

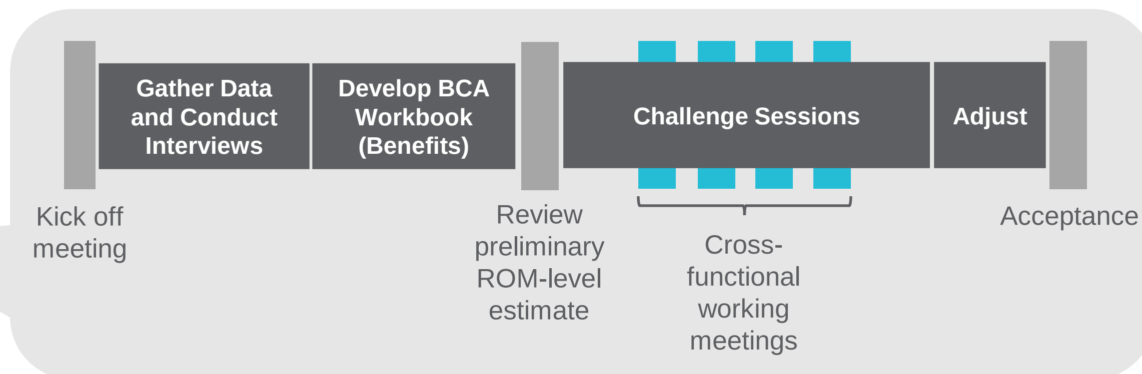
# Digital Modernization Project Development

**The safety system modernization project is being developed in a staged approach and has focused on collecting, analyzing and consolidating benefits and cost data as inputs to the business case.**

## Stage I-A
## Scope Development

- Concept of Advanced Operations
- Stakeholder Needs Assessment
- Functional Requirements Specification
- Vendor Qualification

**High-Level Project Development Plan**




## Stage I-B
## Business Case Development (BCA)

- ATWSMS/RPS Business Case Benefits Analysis
- ECCS/N4S Business Case Benefits Analysis
- Develop Project Implementation and Ongoing Cost Data*
- Develop Preliminary Business Case (ScottMadden and EPRI Model)

## Stage II
## License Amendment Request (LAR) Activities

## Stage III
## Implementation Planning

## LWRS Coordination and Research Support

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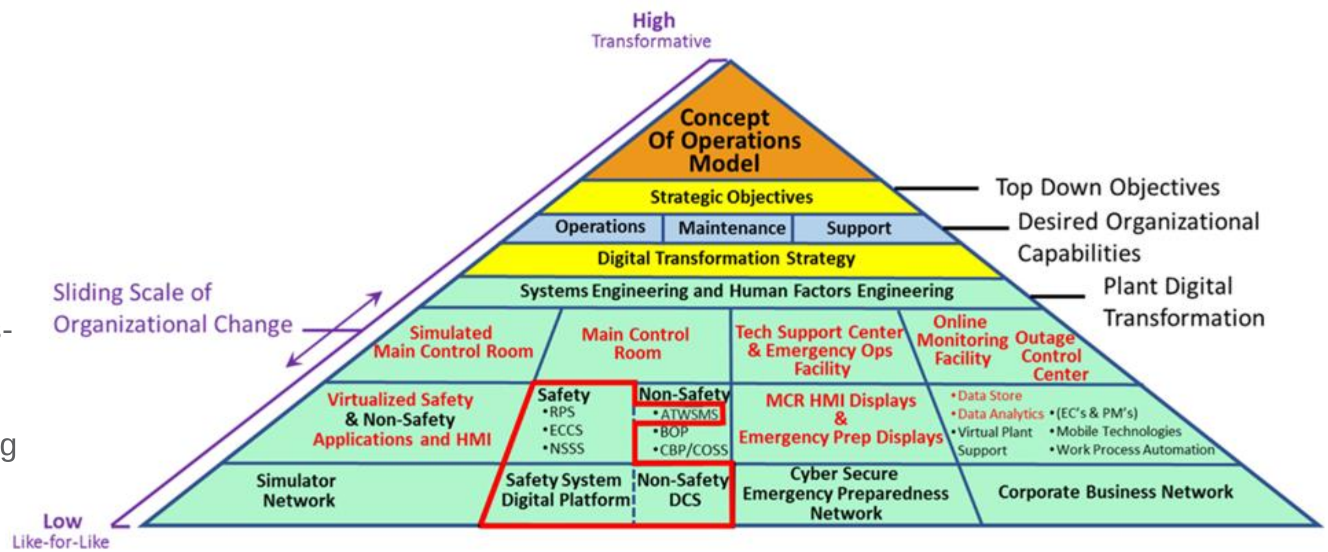
* Data provided by Owner's Project Team

# Advanced Concept of Operations

**The Advanced Concept of Operations drives transformative enterprise change the from the top down.**

- Historically there has been no roadmap for performing a large-scale digital transformation of currently operating nuclear plants to extend their technical longevity, while at the same time reducing their operating and maintenance (O&M) costs
- This concept of operations model establishes top-down objectives and constraints for all simulator, plant protection and control, emergency preparedness, and business functions as an integrated set (shown in green). This promotes a business-driven, technology centric, digital transformation strategy. This supports a smaller onsite staff footprint, while increasing the safety, reliability, and situational awareness and improves focus on daily plant operations.
- The LWRS plant modernization pathway has developed a design concept for first-echelon BWR safety system I&C upgrades as a key enabler for a larger concept of operations that moves an existing plant from a labor-centric analog domain to a technology-centric digital domain. This is illustrated in the graphic to the right

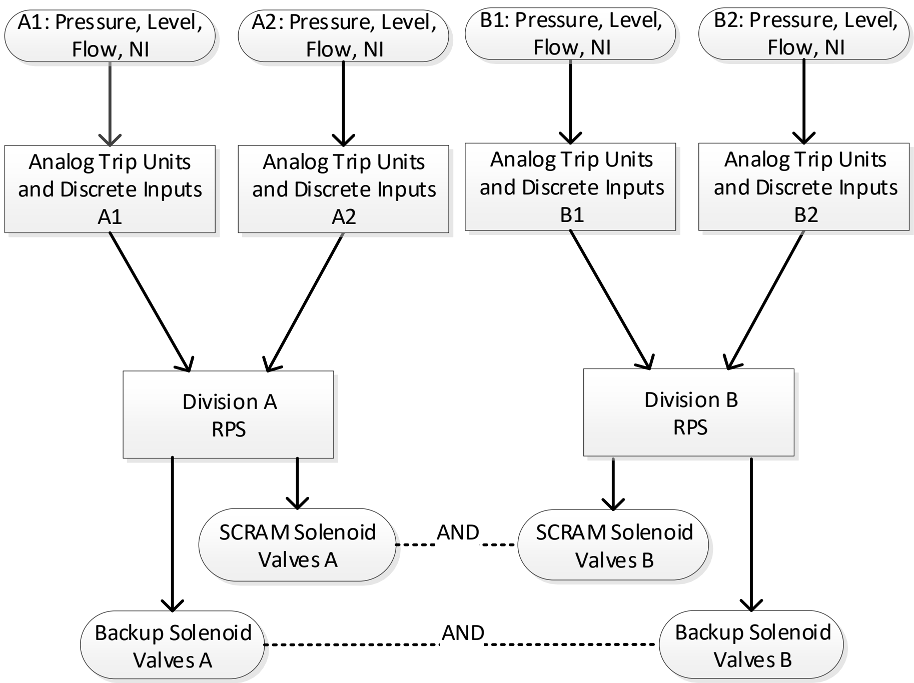



**Safety-Related I&C Enables Advanced Concept of Operations Functions**
A full Digital Transformation is realized by the multi-tier digital system infrastructure depicted above.

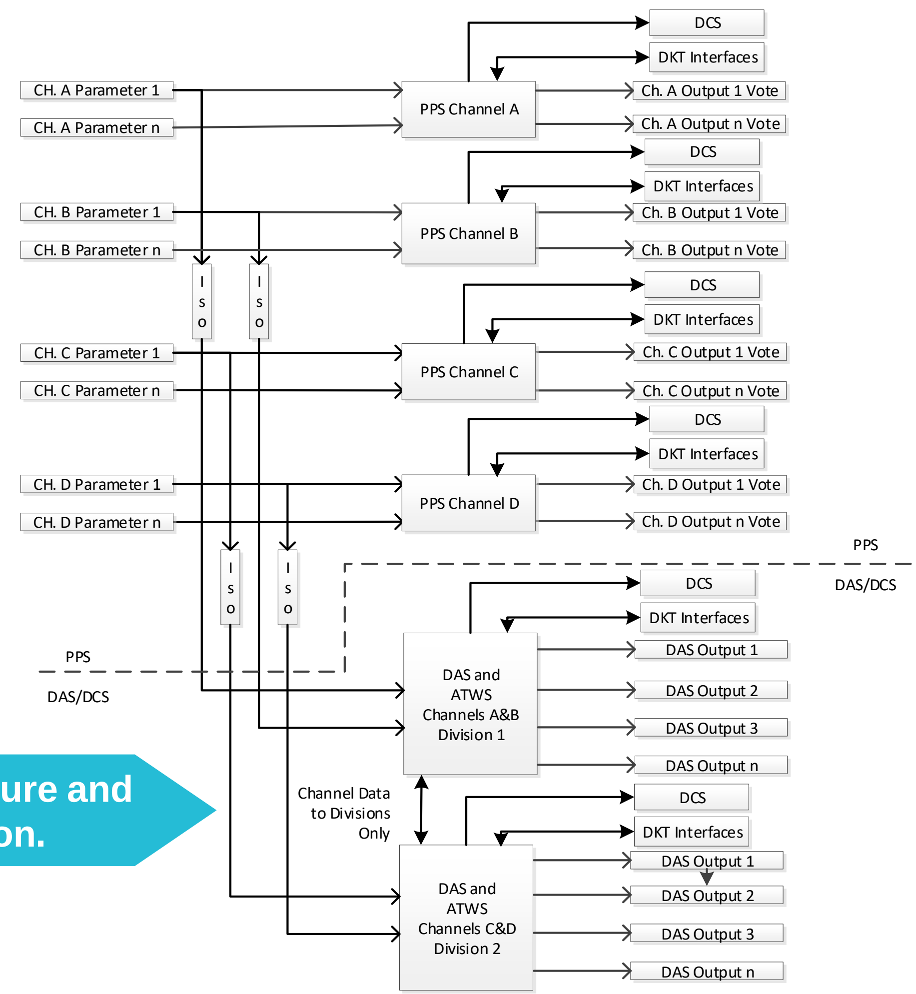
# System Architecture

# High-Level Digital Safety System Enhancement

## Current System Architecture - RPS (N4S and ECCS similar)




## Modernized Plant Protection System Architecture




**The modernized system supports a more streamlined architecture and eliminates redundant field components and instrumentation.**

# Business Case Methodology

# Business Case Development Summary

**The BCA methodology was drafted to systematically evaluate and forecast expected lifecycle costs for the safety-related I&C systems targeted for modernization.**

Project Team/SME Data Validation Sessions

### Develop Basis for BCA

- Define targeted systems for modernization
- Propose improvements
- Catalogue expected benefits
- Conduct initial SME interviews scope
- Prepare preliminary engineering studies to bound the scope

### Collect, Synthesize, and Verify Data

- Mine data sources for insights into material, labor, and indirect costs
- Filter, assemble, and categorize cost data
- Verify cost data and implications with SMEs

### Quantify Benefits

- Consolidate labor benefits across systems to realize economies of scale
- Forecast material price trends to calculate anticipated savings
- Calculate anticipated benefits
- Verify benefit estimates with Owner and SMEs

### Conduct Cost-Benefit Analysis

- Incorporate project costs into the analysis
- Review business case analysis and incorporate SME and Owner feedback
- Review results with Owner
- Share blinded findings with industry

Project Team/SME Challenge Sessions

# System Benefits

# Quantitative & Qualitative Benefit Enablers

- Project benefits rely on several essential enablers that are inherent or specified features of the digital upgrade including:
  - Quantitative Benefit Enablers (included in the BCA)
    - Self-Diagnostics
    - Unidirectional Data Flow
    - Application Software
    - Sensing Instrument Reduction
    - Redundant/Modernized Power Distribution Units
    - Solid-State Electronics
    - Lifecycle Support Strategy
  - Qualitative Benefit Enablers (not included in the BCA)
    - Standardized Cyber Security
    - System Integration Capabilities
    - Simulator Integration Capabilities
    - Hybrid Interface Capabilities
    - Switched Display, Keyboard, and Trackball (DKT) Concept
    - Safety-Related DKTs
- Strategic selection of design features for the Plant Protection System (PPS) and the Distributed Control System (DCS) onto which ATWSMS functions will be migrated drives additional cost savings

# Labor Benefits

- Data-mined and analyzed from the Station's historical work management system (WMS) data annual workload reductions in the following activities:
  - Surveillances and Tests (ST)
  - Preventive Maintenance (PM)
  - Corrective Maintenance (CM)
  - Event Management and Corrective Action Program (CAP)
  - Training
  - Overtime
- Created In-Scope Equipment List to identify equipment impacted by the modernizations
- Identified historical Work Orders (WOs) from plant data systems associated with impacted equipment and classified into two categories:
  - Planned Work (impacted ST and PM WOs)
  - Unplanned Work (impacted CM WOs)
- Mined WOs for task information, aggregated into data lists for each WO type (e.g. ST, PM, etc. from above)
  - Compared lists to the Planned Maintenance Item (PMI) list from the Station's WMS to determine which PMIs were impacted and quantify the workload reduction
  - Used Planned Maintenance ID (PMID) as a unique identifier for each PMI that WOs could be mapped to in order to generate workload reduction estimates
  - Where work orders were not eliminated, applied percent workload reductions
- Estimated unplanned work labor reductions by averaging historical labor associated with CM WOs for impacted equipment over the last five years and trending this average into future years
- Validated potential workload reductions with station personnel

# Labor Benefits (cont.)

- Evaluated Incident Reporting and Event Management workload reductions by analyzing Station's CAP incident data and assessing (with SME input) if they were caused by in-scope equipment failure
- Analyzed System Engineering, Supply Chain and Warehousing, Training, and Contract Labor for potential labor benefits (only System Engineering labor benefits ultimately credited to the project)
- Classified workload reductions as harvestable or unharvestable using the following requirements:
  - Harvestable
    - Online workload reductions from the ST, PM, and CM WOs
    - Must be equal to or greater than one Full Time Employee (FTE) in resource-hours to be counted in the BCA
  - Unharvestable
    - Outage workload reductions, which are supported by external labor sourced from contracts or from other Stations
    - An FTE reduction not supported by cumulative data, regulatory requirements, or specificity of roles
- Considered unharvestable reductions in the BCA as redeemable reductions of temporary support, contracted or otherwise, transferred from other stations
- Unharvestable partial FTE benefits were taken as overtime savings for those positions where eligible

# Material Benefits

- Used two data sources – the Station WMS and Procurement System – for material expenditure savings analysis and a Catalog Identification Number (CATID) as the common data key between the two
- Mined components in in-scope historical WOs from the WMS and used their CATIDs used to identify relevant items in the station procurement system
- Logged key purchase information for each relevant component, including:
  - Historical purchases (quantity, unit price and purchase year) over the past 10 years
  - Most recent purchase price paid for the component
  - Average expenditure over the most recent five years
  - Current quantity in inventory
- Calculated a weighted average Compound Annual Growth Rate (CAGR) for the price of system components using this information.
  - CAGR used to adjust historical purchase prices and estimate current and future inventory value
- Examined inventory cost impacts, including inventory carrying costs, annual depreciation, supply chain and warehousing charges, property taxes, insurance, and one-time write-down costs
- Performed extensive data and historical pricing analysis around material escalation rates of individual components (particularly for the ATWSMS) to determine if obsolescence was a factor in rising system costs.
  - The results of this analysis are provided in Annex A of this report

# Benefits Summary

# Direct Annual Benefits*

**Digital modernization of the ATWSMS, RPS, ECCS, and N4S systems results in harvestable resources and annual cost savings:**

### Direct Labor

Equipment operator or equivalent crew resources[1]

I&C craft resources

Maintenance prep resources

**8-12 Harvestable FTE Resources**

### Contract Labor

Outage I&C contract labor

**4k – 6k annual hour reduction**

**Contract I&C Labor Resources**

### Other Labor

$100k

Reduction in non-harvestable labor overtime costs

**Overtime Savings**

### Material and Tools

Reduction in the cost of materials[2]

**$1.5M – 2.0M**

**Materials Savings**

**>$4.0M** **in harvestable annual cost savings associated with this Digital Modernization**

**Harvestability is the actual reduction in FTEs allowed by a reduction in workload, notwithstanding regulatory staffing requirements.**

***All figures presented herein are illustrative of scale of estimated project costs and benefits, and are not intended to present actual data utilized in the Owner's business case analysis.***



1. Not accounting minimum staffing requirements.
2. Excluding carrying cost of inventory.

# Other Benefits and Avoided Costs*

**Digital modernization of the four safety-related systems results in resource efficiencies and avoided annual costs:**

**Unharvestable Direct Labor**

**6,000 Hrs**

### Workload Efficiencies

Workload savings in addition to harvestable FTE reductions

**Material and Tools**

**$900K**

### Capital Carrying Cost

Opportunity cost of maintaining inventory of materials and components related to the system

**$50-$200 Million****

### Material Escalation

Avoided escalation cost of ATWSMS materials thru remaining plant operating license

**Other Costs**

### Outage Support Efficiencies

Savings in support of fewer I&C craft laborers required during outage

**Other Costs**

### Backlog Reduction

Avoided cost in backlog reduction

**Other Costs**

### Training Content and Delivery Reduction

Avoided cost in Training delivery

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**Represented as 2020 dollars

# Project Financial Metrics

# Business Case Analysis Aggregate Results*

**The financial metrics yielded by the BCA demonstrated a positive business case for the owner.**

**Project Costs**

## Capital Costs: $70M - $120M (2 Units)

## Ongoing O&M**: $150k annually

| Net Present Value*** | Internal Rate of Return*** | Payback Period |
|---|---|---|
| **$50M to $80M** | **12% to 18%** | **12 to 15 years** |

**All figures presented herein are illustrative of scale of estimated project costs and benefits, and are not intended to present actual data utilized in the Owner's business case analysis. Use of EPRI Business Case Analysis Model tool produced results consistent with those presented here.*

***O&M costs inclusive of labor and materials*

****Based on a model term consistent with the operating license of the Station*

# Annex A – Material Obsolescence Case Study

# Case Study: Material Obsolescence*

**Based on early interviews with plant staff, the team conducted an investigation into reports of high escalation of analog component costs for one of the systems. An analysis of purchasing history of components revealed that material costs are increasing at compound annual growth rate (CAGR) of over 20 percent.**

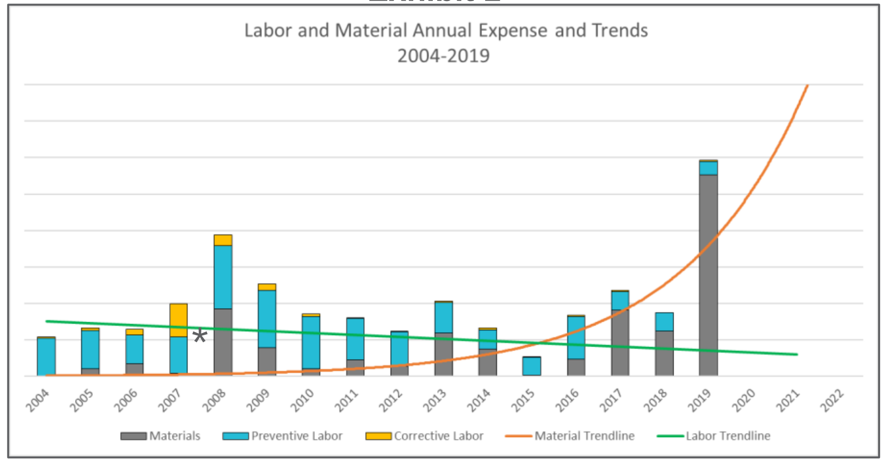
## Continued growth of material costs has made maintaining/supporting the existing system uneconomic

- Although cost management efforts have reduced the annual cost of labor to maintain the system, these gains are offset by growth in cost of materials (Exhibit 1)
- Annual material expenditure increases are driven by both escalating component unit prices and increasing failure rates
- Replacement components are harder to find, resulting in more supply chain and engineering time spent trying to procure the parts
- Limited supplier base is one factor driving the high price of these components

## Escalating analog component unit prices are driving 80-90% of annual material expenditures

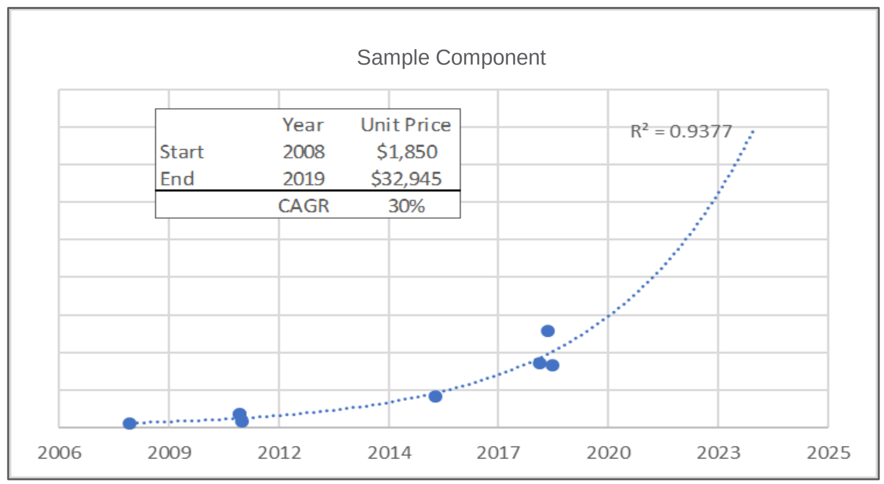
- Unit price growth rates were determined by fitting best-fit trendlines to historical purchase data of components
- Double digit growth rates were demonstrated for many of the frequently exchanged components. For example, a growth rate of 30% was observed for a representative component from 2008 to 2019 (Exhibit 2)

**Exhibit 1**




** Abnormal increase in corrective maintenance 2007, which corresponds with an increase in materials cost in 2008-2009.*

**Exhibit 2**

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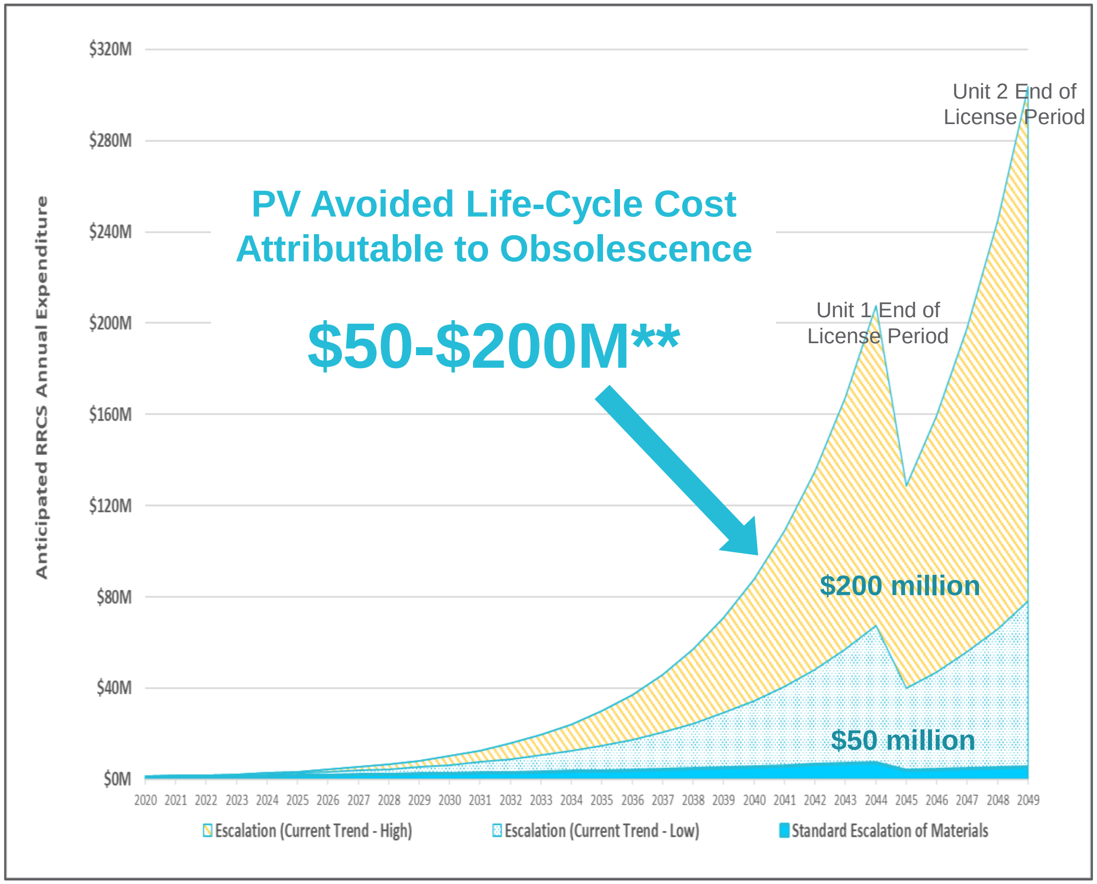
# Case Study: Material Obsolescence* (Cont'd)

**The present value of avoided cost attributable to obsolescence for material expenditures and reduced capital carrying costs enabled by replacing the system is $50–$200 million.**

## Key Inputs for Present Value

- Future expenditures were calculated using current 3-year average material expenditures as a base and escalated for future years using rates determined by statistical analysis of purchase data
- Three growth rate scenarios were analyzed to determine the impact of the materials CAGR on project present value (as seen in the graphic to the right)




## Present Value Analysis

- Anticipated annual expenditures* discounted to current dollars (graphically represented as the area under the curve)

## Other System Component Obsolescence

- A similar methodology was applied to material expenditures of other systems and found that escalation of material expenditures were approximately 8% (higher than expected rate of 5%)
- The results of these analyses were applied to the overall business case (i.e., escalation rates determined for each system were applied accordingly to determine future cash flow benefits)

***Anticipated expenditures assumes that system components will be available for purchase throughout the station's life cycle.**

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