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Revision 0

Light Water Reactor Sustainability Program

Integrated Operations for Nuclear: Work Reduction Opportunity Demonstration Strategy

September 2023

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Integrated Operations for Nuclear: Work Reduction Opportunity Demonstration Strategy

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EXECUTIVE SUMMARY

The Light Water Reactor Sustainability Program Plant Modernization Pathway has been working with industry for a number of years to leverage digital technology to extend the life and improve the performance of the existing fleet through modernized technologies and improved processes for plant operation and power generation. This includes the development of modernization solutions to improve reliability and economic performance while addressing the US nuclear industry's aging and obsolescence challenges. The objective of these efforts is to deliver a sustainable business model that enables the US nuclear industry to remain competitive.

Digital Infrastructure (DI) research has established a technical foundation for these efforts. This effort began with technical analysis and support for a safety-related instrumentation and control (I&C) pilot upgrade being performed at Constellation Energy Generation's Limerick Nuclear Plant. The following publicly available reports were produced as part of this effort.

- INL/EXT-20-61079, Vendor-Independent Design Requirements for a Boiling Water Reactor Safety System Upgrade [1]
- INL/EXT-20-59371, Business Case Analysis for Digital Safety-Related Instrumentation & Control System Modernizations [2]
- INL/EXT-20-59809, "Safety-Related Instrumentation and Control Pilot Upgrade: Initial Scoping Phase Implementation Report and Lessons Learned [3]
- INL/RPT-23-72105, Safety-Related Instrumentation and Control Upgrade: Conceptual – Detailed Design Phase Report and Lessons Learned [4]

More generalized Digital Infrastructure (DI) research provides an expansive and holistic view of these efforts. The following publicly available were produced to achieve this end:

- INL/EXT-19-55799, Addressing Nuclear I&C Modernization Through Application of Techniques Employed in Other Industries [5]
- INL/EXT-21-64580, Digital Infrastructure Migration Framework, [6]

Reference 6 also presents information with regard to the allocation of Data Architecture and Analytics (DA&A) application capabilities to different levels of the DI based on the functionality they provide in relation to cybersecurity rules and guidelines.

At the same time, Integrated Operations for Nuclear (ION) efforts have been focused on changing the operations model for nuclear plants from one that is labor-centric to one that is technology-centric. With the expectation that a sufficient DI will be in place, ION researchers have endeavored in collaboration with industry to identify Work Reduction Opportunities (WROs). Initial ION WROs were identified and then generically evaluated for industry application with technology expected to be available to support implementation in a three to five-year time frame. This information is captured in the following publicly available documents:

- INL/EXT-21-64134, Process for Significant Nuclear Work Function Innovation Based on Integrated Operations Concepts [7]. This report identifies 37 WROs through collaboration with industry and demonstrates a high-level approach to implementing these WROs to drive operation cost reductions.
- INL/RPT-22-68671, Integrated Operations for Nuclear Business Operation Model Analysis and Industry Validation [8]. The purpose of this report is to refine and analyze nine groupings of work reduction opportunities first presented in [7] to better estimate potential operating and maintenance cost savings for their implementation.

INL/RPT-23-74393, *Pilot Business Case Analysis for Digital Infrastructure* [9], documents efforts to synergize DI and ION research. In this case, a plant Owner (Luminant) of a two-unit Reference Plant (Comanche Peak) is looking to perform significant safety-related and non-safety related I&C upgrades to address obsolescence, maintain or improve reliability and reduce operating and maintenance cost (O&M). The Owner is also looking to implement other digital upgrades to realize WROs to further O&M costs and address labor shortages.

Reference [9] shows net positive business case results for both I&C upgrades and digital implementations of select WROs. The Owner identified four specific categories of ION WROs as an initial, viable subset of interest. These include:

1. Mobile Worker Technology
2. Condition Based Monitoring
3. Advanced Training Technology
4. Software Application Assisted Business Processes

These were identified by the owner as being both high priority and technically implementable in the near term.

This document leverages these select ION WROs as identified in Reference [9] as a starting point to initiate a specific WRO demonstration strategy. The strategy addresses the select ION WROs categories described above with the intent of applying this outline to other WROs in the future. A fifth WRO category for emergency response was also identified when developing this document to demonstrate how synergy between individual WRO implementations on the DI can provide additional capabilities and savings with limited additional costs.

This strategy will be leveraged by planned future research to more fully mature the process for the identification of specific and available technologies to implement specific WROs within the five categories discussed above. This strategy will also be used to establish specific implementation techniques for representative candidate technologies for those five WROs categories as well as additional WROs as resources allow. This WRO maturation is intended to produce sufficient technical and business case information to enable a pilot utility to approve specific WRO-related project(s) for implementation. This will demonstrate to industry a path forward to realize ION WRO implementation savings.

CONTENTS

FIGURES

TABLES

ACRONYMS

AI	Artificial Intelligence
ANSI	American National Standards Institute
ATWS	Anticipated Transient Without Scram
BCA	Business Case Analysis
BWR	Boiling Water Reactor
CEG	Constellation Energy Generation
CPNPP	Comanche Peak Nuclear Power Plant
CR	Corrective Action (Program)
DA&A	Data Architecture and Analytics
DCS	Distributed Control System
DI	Digital Infrastructure
DWP	Dynamic Work Package
ECCS	Emergency Core Cooling System
EOF	Emergency Response Facility
EP	Emergency Preparedness
EP-Net	Emergency Preparedness Network
EWP	Electronic Work Package
EPRI	Electric Power Research Institute
ERDS	Emergency Response Data System
ERO	Emergency Response Organization
FY	Fiscal Year
Gen	Generation
I&C	Instrumentation and Control
IRR	Internal Rate of Return
INPO	Institute of Nuclear Power Operations
IT	Information Technology
HFE	Human Factors Engineering
HSI	Human-Systems Interface
HTI	Human-Technology Integration
ION	Integrated Operations for Nuclear
LGS	Limerick Generating Station
LWRS	Light Water Reactor Sustainability (Program)
MCR	Main Control Room

NPV	Net Present Value
N4S	Nuclear Steam Supply Shutoff System
O&M	Operations and Maintenance
OSC	Operations Support Center
PTPG	People, Technology, Processes and Governance
PWR	Pressurized Water Reactor
NRC	United States Nuclear Regulatory Commission
PM	Plant Modernization
RG	Regulatory Guide
RO	Reactor Operator
RPS	Reactor Protection System
SRO	Senior Reactor Operator
TCO	Total Cost of Ownership
TSC	Technical Support Center
VR	Virtual Reality
WRO	Work Reduction Opportunity

Integrated Operations for Nuclear: Work Reduction Opportunity Demonstration Strategy

1. INTRODUCTION

1.1 Plant Modernization Pathway: Interconnected Research Areas

The Plant Modernization (PM) Pathway of Light Water Reactor Sustainability (LWRS) Program is focused on deliberately applying digital technology to enhance the ability of existing nuclear plants in the United States to operate for a total lifetime of 80-100 years. These plants are currently managed using a labor-centric operations model that is increasingly inefficient and costly to operate and sustain when compared to modern generation plant operations such as a natural gas combined cycle plant or other comparable heavy industry such as petrochemical facilities.

The Integrated Operations for Nuclear (ION) concept, developed by the LWRS PM Pathway, provides a comprehensive, business case-driven strategy to support Plant Modernization for the U.S. nuclear fleet. Its primary objective is to transition the existing labor-centric operating model into one that is increasingly more technology-centric. ION business transformation aims to maintain or improve plant safety and operating capacity factor while reducing total ownership cost (TOC) for the remainder of plant life. These objectives are shown at the top of Figure 1.

<table>
<tr><th colspan="5">Plant Modernization Research Objectives and Goals</th></tr>
<tr><td>Objectives</td><td colspan="4">Extend the life and improve the performance of the existing fleet through modernized technologies and improved processes for plant operation and power generation.

Develop modernization solutions that improve reliability and economic performance while addressing US nuclear industry's aging and obsolescence challenges.

Deliver a sustainable business model that enables US nuclear industry to remain competitive.</td></tr>
<tr><td>Research Areas</td><td>Digital Infrastructure</td><td>Data Architecture & Analytics</td><td>Human & Technology Integration</td><td>Integrated Operations for Nuclear</td></tr>
<tr><td>Outcomes</td><td>A multi-layered, sustainable digital foundation to enable plant modernization</td><td>Advanced monitoring and data processing to replace labor-intensive support tasks</td><td>Tools and methodologies that maximize efficiency while ensuring safety and reliability are maintained</td><td>Light water reactor fleet electric market competitiveness</td></tr>
</table>

Figure 1. LWRS PM pathway objectives and goals.

A complementary digital technology strategy is necessary to provide the foundation to host applications that are used both to directly operate the facility (through instrumentation and control [I&C] systems) and to perform the other necessary tasks to most efficiently run the business of a nuclear plant. This is shown as the far left under Digital Infrastructure (DI) with associated outcomes. This technology strategy is captured in INL/EXT-21-64580, "Digital Infrastructure Migration Framework." [6] A simplified depiction of the proposed DI is provided in Figure 2The simplified DI generic framework diagram for nuclear, as shown in Figure 2 is adapted from the Purdue Enterprise Reference Architecture (Purdue Model) that has been in generic industry use since the 1990s. Each Purdue Model level is cross-referenced by function to NRC cybersecurity levels as shown on the left of Figure 2 as established in Regulatory Guide 5.71, "Cyber Security Programs for Nuclear Facilities" [10]. Each Purdue Model Level consists of hardware and configuration/utility software (e.g., firmware, hardware resource management tools, operating systems, programming tools, self, diagnostic tools, and cybersecurity monitoring tools).

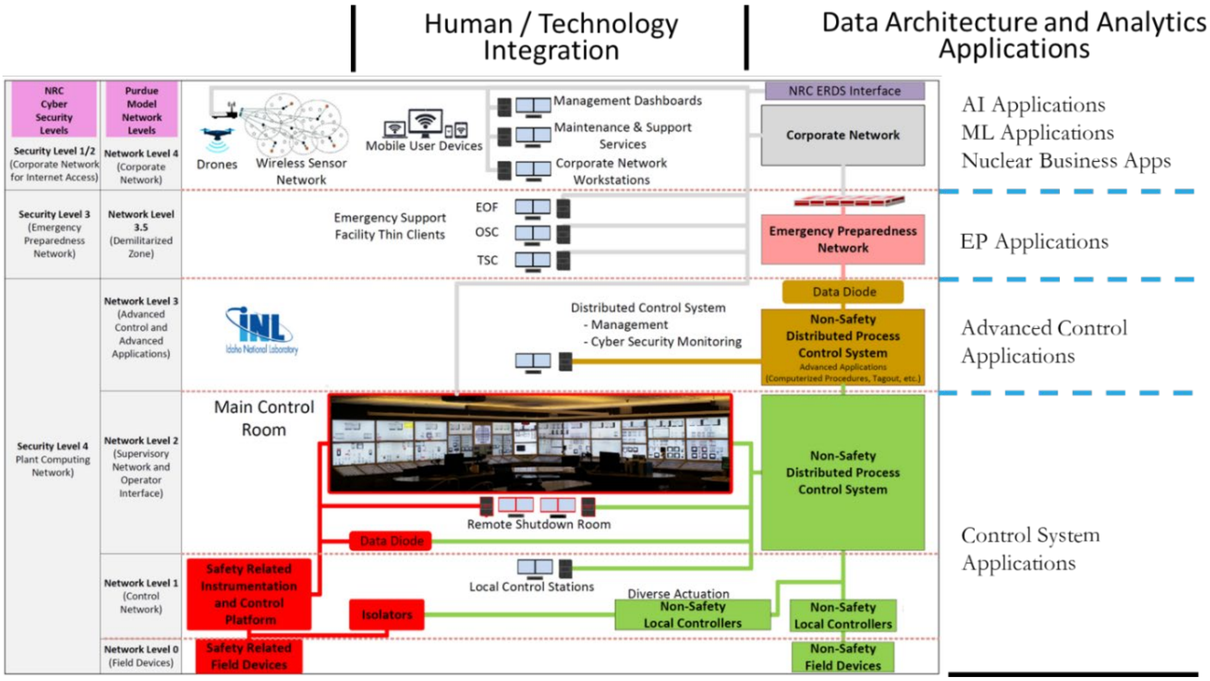

Figure 2. Simplified Digital Infrastructure diagram.

The DI provides a comprehensive physical and logical foundation to support Digital Architecture and Analytics (DA&A) applications. Determination of needed DI capabilities as well as DA&A application capabilities to be hosted on the DI (as shown on the right of Figure 2) to achieve a technology-centric concept of operations is accomplished by performing business case analyses. Technologies chosen are ideally identified in a manner that fosters integration so that the result can provide much more capability than the sum of its aggregate parts. Obsolescence management of digital technology also must be considered carefully when choosing technologies for implementation.

Human-Technology Integration (HTI) utilizes tools and methodologies that maximize efficiency while ensuring safety and reliability are maintained A pictorial representation of how DI, DA&A, and HTI relate is shown at the top-center of Figure 2 and detailed in Figure 3.

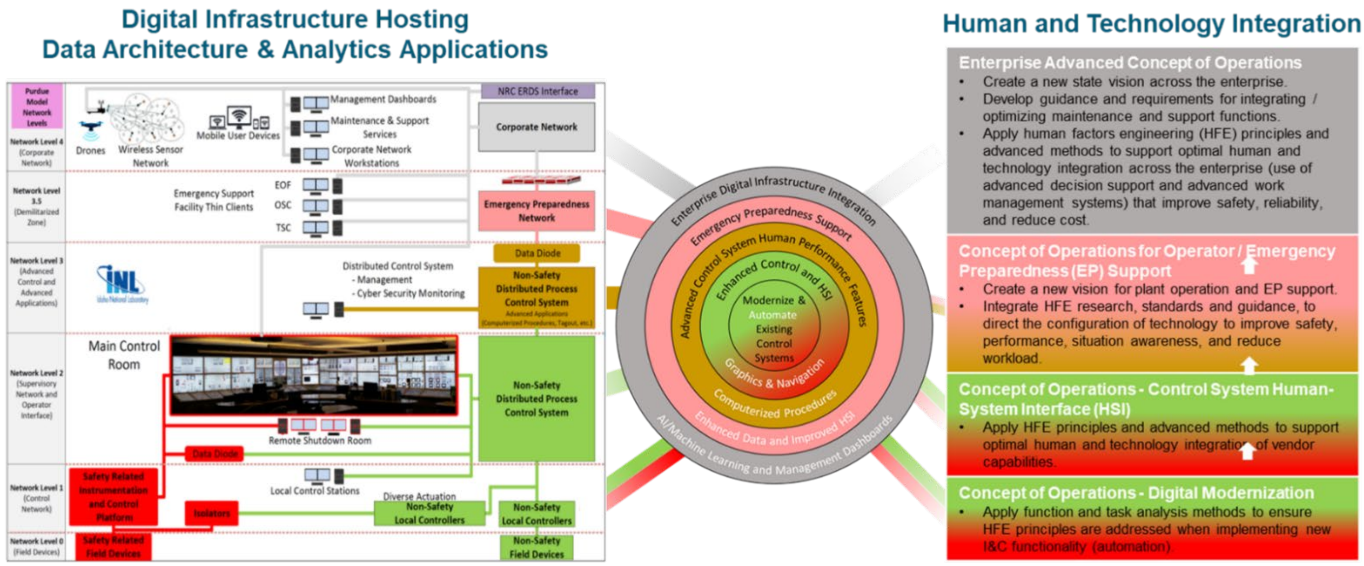

Figure 3. Relationships between DI, DA&A, and HTI.

The union of the DI with DA&A software applications activities provides powerful capabilities. This union is represented on the left side of Figure 3 as the colored digital platforms at the different Network Levels that make up the DI. Proper utilization of these capabilities must consider their usability by personnel at all levels of the DI. This is accomplished through digital HSIs depicted at Network Levels 1 through 4 as shown both in the center of Figure 2 and the left of Figure 3.

The color coding of the individual subsystems that make up each of these Network Levels shown in the DI flow from left to right across Figure 3 to support a transformational advanced concept of operations holistically. As shown in the "target" in the center of Figure 3, DI and DA&A capabilities (shown in black text) correspond with automation and HSI capabilities (shown in white text in the target) that are then implemented at each level of the Purdue Model shown in the HTI column on the right side of Figure 3 (with white text headings). The result enables a transition from the current state concept of operations to a single, comprehensive, DI and DA&A enabled advanced concept of operations.

1.2 Integrated Operations for Nuclear: Concept of Operations and Associated Work Reduction Opportunities

Applying digital technology by itself to the existing plant concept of operations can provide some opportunities to reduce O&M costs. In order to achieve the envisioned transformation of the business of running a nuclear plant from the existing labor-centric operating model to one that is increasingly technology-centric, a corresponding transformational change of the plant concept of operations is required. The following subsections provide a general discussion of both the current state concept of operations and a transition to the envisioned new state to provide the context for ION work reduction opportunity (WRO) implementation.

1.2.1 Generic Current State Plant Concept of Operations

Figure 4 provides a simplified depiction of a generic, current state plant concept of operations for existing nuclear plants. While this discussion is referenced around a plant view, for a utility with a fleet of nuclear units, variations of the same model would apply to them all individually or to the whole fleet.

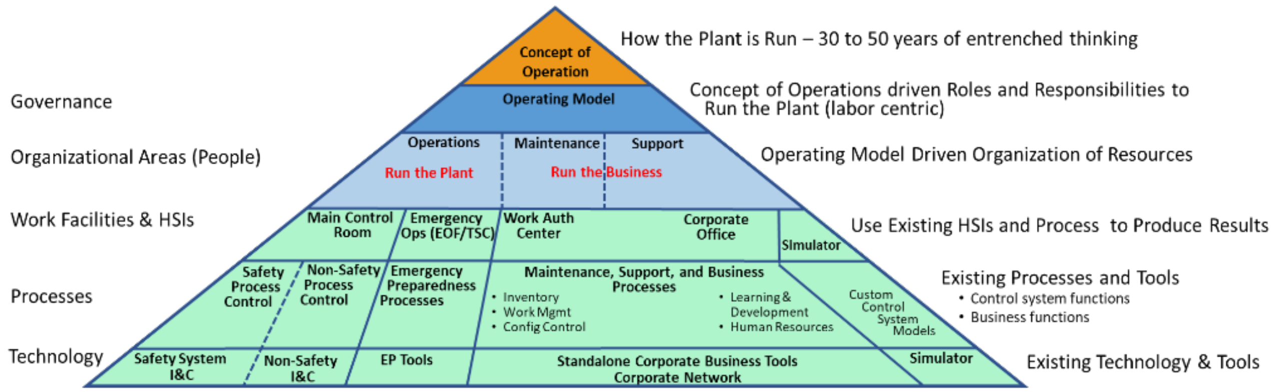

Figure 4. Current state Concept of Operations diagram.

The top two layers of the pyramid shown in Figure 4 depict the existing overall concept of operations and the governing operating model associated with it. The current concept of operations is focused on maintaining safety margins and maintaining or improving plant capacity factors. This has resulted in high levels of operational performance and capacity factors of over 93% for the U.S. commercial nuclear fleet. Efforts to establish and maintain this continued level of safety and operational performance, however, have largely been focused on the implementation and enhancement of existing labor-centric processes such as:

- 10 CFR 50.65, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," also known as the "Maintenance Rule" [11]
- The Institute of Plant Operators (INPO) AP-913, "Equipment Reliability Process" [12]
- The Mitigating System Performance Index (MSPI) and associated system health reports
- The Corrective Action (CR) Program at each nuclear site
- Many other processes are associated with running the business of a nuclear plant.

This paper does not in any way intend to cast dispersions on this operating model. It has served the industry well for years and has resulted in the safe operation of the commercial nuclear fleet in the United States, while achieving the highest availability factors in the world. The challenge is that the O&M costs to sustain such a model with antiquated technology are increasing, which is significantly impacting the competitive position of U.S. nuclear power production. Critical existing technologies (such as safety-related I&C systems) are at or beyond their forecast useful life and are not sustainable.

The labor-centric nature of this model is driven by several factors, including the existing technologies, processes, and work facilities/human-system interfaces (HSIs) available at the plant. These elements are represented as the bottom three levels in Figure 4. A summary of current technologies employed is shown below:

- Safety-related I&C systems: Many of these systems are either analog or, in some cases, first-generation digital systems. The cost for replacement parts is increasing and finding such parts is becoming more difficult over time. The skill of craft to maintain these obsolete systems is also waning. Investments in these systems also do not provide an avenue to improved performance (e.g., increased levels of automation, redundancy, reliability, and self-diagnostics
- Non-safety I&C systems: These systems comprise a mix of direct-acting manual controls, analog control systems, electro-hydraulic/mechanical, pneumatic, and point solution digital systems. Some limited distributed control systems have been installed to upgrade certain technologies.

- Emergency Preparedness tools: These tools exhibit varying technology levels, ranging from telephone communications to point solutions or networked digital systems.
- Corporate Business tools: These tools vary from manual paper processes and the use of standalone software packages to networked databases and tools.

This current concept of operations and the associated, technology driven, labor-centric operating model are the root of the operating philosophy of many existing plants. The three fundamental organizational areas (operations, maintenance, and support) where people are assigned to implement the concept of operations and operating model are shown at the third level from the top in Figure 4. For the purposes of this report, these three organizational areas are defined more specifically and grouped differently. This is to align the current operating model described in this section with the new-state operating model described in Section 1.2.2 and associated business case efforts,

"Operations" as shown in the third layer from the top of Figure 4 supports activities that directly relate to operating the plant to produce power and to support emergency preparedness functions. This is the organizational area necessary to "run the plant" as shown in red above. The "maintenance" and "support" organizational areas as shown in Figure 4 are grouped as the necessary organizational areas to "run the business" of a nuclear plant. This is also shown in red above. This does not diminish their importance. To illustrate, the "run the plant" operations area personnel must be available continuously (plant operators) or on call (to support emergency preparedness functions) to permit plant operation. Maintenance and support personnel largely work business hours except during workups and to perform outage maintenance. However, if the "run the business" function is not performed, the plant will soon be unable to operate because of equipment failures or failure to meet regulatory commitments.

1.2.2 Digitally Enabled ION New State Concept of Operations

Figure 5 provides a depiction of a digitally enabled new state concept of operations that is intended to enable the replacement of the current labor-centric model with one that is technology-centric.

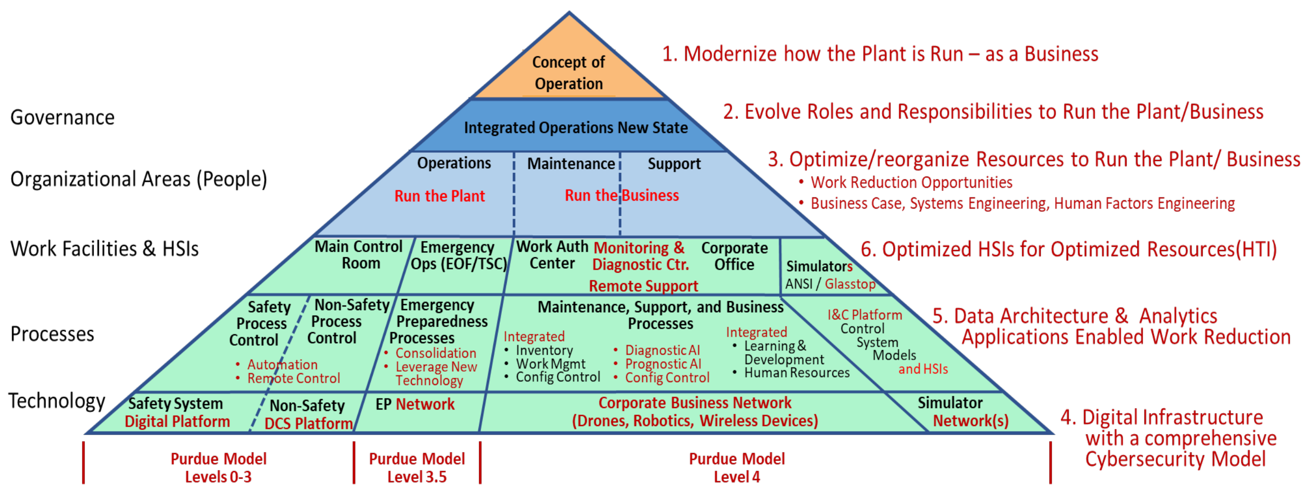

Figure 5. ION enabled new state Concept of Operations diagram.

As can be seen, Figure 5 does not fundamentally alter the "what" when it comes to providing the basic outcomes of the current concept of operations model shown in Figure 4. The need to "run the plant" and "run the business" is still necessary. What is proposed is changing "how" these outcomes are achieved by applying comprehensive DI associated DA&A applications across the enterprise. This technology-centric concept of operations is proposed to lower TOC while addressing obsolescence and cybersecurity concerns associated with digital systems.

ION documentation refers to people, technology, processes, and governance (PTPG) that support any concept of operation construct. These items appear to the left of both Figure 4 and Figure 5. Coupling the ION concept with the application of DI, DA&A applications, and HTI provides a mechanism to reallocate current labor and rely on technology and automation to streamline selected work activities. Utilities may also centralize or outsource source certain tasks (e.g., engineering, fuels) to vendors to more efficiently accomplish those tasks.

1.2.2.1 Work Reduction Opportunity Identification

The approach used to achieve this is outlined in the description of the six items shown to the right of Figure 5, as detailed below.

1. Modernize how the plant is run – as a business (item number corresponds to Figure 5)

   The plant concept of operation is modernized through the application of digital technology as justified by business case analyses to provide maximum operational and financial benefit. Equipment obsolescence issues impacting current operation are addressed. The modernizations allow the harvesting of intellectual property to deal with digital obsolescence to minimize TOC for remaining plant life.

2. Evolve roles and responsibilities to run the plant/business (item number corresponds to Figure 5)

   Labor-intensive work activities are accomplished by identifying WRO opportunities enabled by technology. These WROs are identified by evaluating the major resource drivers that drive O&M costs at the plant. Expected direct workload O&M savings are identified by identifying the method by which technology can be applied to perform the activity to reduce, consolidate, or eliminate the need for human labor. Costs to implement this technology upgrade are also estimated.

3. Optimize/reorganize resources to run the plant/business (item number corresponds to Figure 5)

   The results of items 1 and 2 for one or more WROs are aggregated and evaluated. Roles and responsibilities of the remaining staff are reallocated to maximize harvestable labor savings through staff attrition. Work may also be centralized at remote locations or outsourced as enabled by technology to achieve cost efficiencies. The number of auxiliary operators in the plant may also be reduced through remote control/automation capabilities provided by modern digital I&C systems. Through this optimization/reorganization effort, aggregate O&M cost savings are realized.

1.2.2.2 Work Reduction Opportunity Implementation Overview

4. Deploy a DI with a comprehensive cybersecurity model (item number corresponds to Figure 5)

   It is expected that utilities will leverage the DI concept depicted in Figure 2 to coordinate their digital modernization efforts as presented in [6]. This is a reasonable expectation driven by:

   a. Utilities that have made and continue to make investments in digital technologies. These investments fall within the boundaries of the DI depicted in Figure 2. The challenge is to leverage and coordinate these investments as one cohesive set which maximizes dataflows and capabilities while reducing workload.
   b. Business case analyses performed to date as captured in [2] for Limerick Generating Station pilot safety-related I&C platform upgrade (which also expands the non-safety distributed process control system at that site) and for the 22 I&C safety-related and non-safety I&C subsystem upgrades being considered at Comanche Peak [9]
   c. ION identified WRO opportunities identified in [8] that leverage DI hosting software applications and HSIs.
   d. The need to coordinate cybersecurity efforts across the DI in the most efficient way possible while addressing regulatory requirements and protecting the business of running a nuclear plant.

Key aspects of this DI solution are shown in the bottom technology layer of Figure 5 in red. These include (but are not limited to):

- Deployment of a two-platform (safety-related and non-safety) digital I&C upgrade solution. This standardizes design efforts and enables the development of long-term obsolescence strategies.
- Consolidation of emergency preparedness (EP) capabilities on a portion of the DI that meets cybersecurity rules, allows for consolidation of these functions, and enables capabilities such as the remote location of the emergency operations facility (EOF) for a single unit and remote and consolidation of EOF facilities for a utility nuclear fleet at a consolidated location.
- Expansion of the existing corporate business network at a plant to:
    - Enable wireless devices (e.g., sensors, robotics, drones, advanced portable HSIs, etc.) to directly gather data digitally
    - Enable aggregation of all digital data in the DI for analysis using DA&A applications hosted on the business network (see #5 directly below).
- Enable advanced main control room simulator features. If properly coordinated, I&C upgrades can be directly leveraged in the simulator. This also facilitates the creation of a glasstop simulator that can be used not only for training but also as an I&C/HSI design tool and a tool to verify and validate HSI designs.

The DI Purdue Industrial Control System Model levels shown on the left in Figure 2 are depicted under the bottom technology layer of Figure 5 in red to show the direct connectivity between the concepts presented in the two figures.

It is expected that for utilities that have already been pursuing significant digital upgrades, these will be aggregated over time to enable the DI construct. Enveloping these efforts in one overarching DI provides for economy of scale, standardization of design, and development of an overarching cybersecurity defensive architecture. How cybersecurity fits into the DI as architected is depicted on the far left of Figure 2. This is explained in detail in Section 2.3 of [6].

5. Data Architecture and Data Analytics applications enable work reductions (item number corresponds to Figure 5)

   Enabled by the DI, specific DA&A applications are identified to provide the necessary functionality (perform processes) at the proper level of the DI to optimally provide the functions needed to realize WROs. Example DA&A application capabilities are identified in red in the process layer of Figure 5. Specific strategies to enable ION identified WROs are the subject of a related research effort which will be completed in the near future.

6. Optimize HSIs for the optimized workforce that remains through human-technology integration (HTI) (item number corresponds to Figure 5)

   In order for the people who will be using the DA&A applications hosted on the DI to accomplish their tasks as efficiently and error-free as possible, a properly developed set of HSIs needs to be developed. HTI research as described in Section 1.1 is leveraged to ensure the safe and reliable use of advanced technologies by personnel. This effort is reflected in updates to the work facilities and HSI layer Figure 5 This also enables new HTI capabilities such as a centralized monitoring and diagnostic center and remote support centers which are shown in red in Figure 5.

1.2.2.3 Integrated Operations for Nuclear: Target States

The overall intent of this effort is to first transition from the current state to a target generation 1 (Gen 1) state as depicted in Figure 6.

Figure 6. Transition from Current State to an ION Generation 1 State.

ION Generation I refers to WRO's that are at a sufficient technology maturity level and would support plant transformation within 3–5 years. The ideal state concept drives which technologies are selected based upon based upon meeting plant needs for the near term while also planning to address obsolescence in the long term. Transition states may be necessary depending on the scope of individual changes and the need to implement them over time (e.g., over more than one outage).

As technology develops over time, it is expected that continuous improvements will be made. This will occur in a periodic cycle as future needs are identified, and business case analyses demonstrate net-positive NPV opportunities to deploy them. This iterative process is shown in Figure 7.

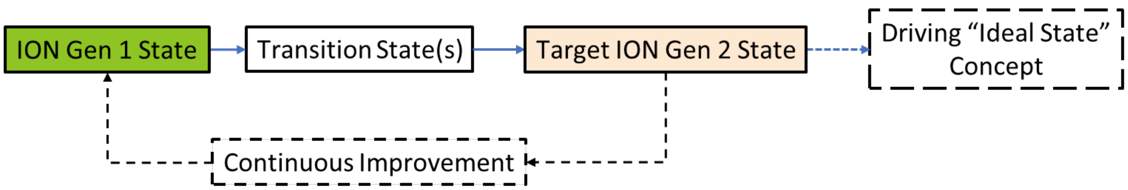

Figure 7. Iteration to an ION Generation 2 State.

In Figure 7, the starting point is the Gen 1 state where improvements are applied to achieve a Gen 2 state. Subsequent target ION states can be pursued for the remaining plant life as business case evaluations of digital upgrades continue to show a positive NPV.

2. PILOT BUSINESS CASE ANALYSES FOR DIGITAL INFRASTRUCTURE AND SUMMARY RESULTS

LWRS PM Pathway researchers have performed two significant DI related business case analyses for two significant industry pilot upgrades. These include:

- INL/EXT-20-59371, *Business Case Analysis for Digital Safety-Related Instrumentation & Control System Modernizations* [2]. This BCA was performed for the industry pilot safety-related digital upgrade at Constellation Energy's Limerick Generating Station (LGS).
- INL/RPT-23-74393, *Pilot Business Case for Digital Infrastructure* [9], This pilot BCA was performed as a larger digital modernization project being proposed at Comanche Peak Nuclear Power Plant (CPNPP) which includes upgrades of 22 safety-related and non-safety I&C subsystems which is intended to be accomplished by leveraging a two platform solution where safety-related I&C functions are migrated to or interfaced with a safety-related digital I&C platform and non-safety I&C functions are migrated to a non-safety distributed process control system (DCS). This BCA analysis also leverages WROs identified by ION researchers to provide a more holistic presentation of integrated cost savings enabled by digitalization.

A summary of the scope and related results of these analyses is provided in the subsections below.

2.1 Digital Instrumentation and Control Upgrade Business Case Analyses

2.1.1 Safety-Related I&C Pilot Digital Upgrade Business Case

The purpose of Reference [2] was to help break the impasse precluding digital safety system upgrades by generating and demonstrating a BCA analysis tool and to use it 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.

The development of a useful BCA methodology required a real-world basis. With the cooperation of Constellation Energy Generation (CEG), the Limerick Generating Station (LGS) was used as the foundation for this research. LGS is a Boiling Water Reactor (BWR). CEG 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/EXT-20-61079 [1] 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. Order of magnitude, non-proprietary results of this effort are provided in Table 1 below.

Table 1. Estimated net present value of safety related I&C upgrade pilot*.

Return Metric	18% Material Escalation	24% Material Escalation
Net Present Value	$30M	$190M
Internal Rate of Rate	12%	19%
Payback Period	15 years	12 years

* This was calculated for a 25-year implementation and utilization period based upon initial project assumptions in the 2020 time frame.

The CEG initiation phase internal project economic analysis was founded on this LWRS BCA research. This provided more well-rounded and detailed material and labor cost data to evaluate the monetary benefit that digital modernization and pursuing the project can enable. This permitted adjusting those benefits as sensitivities to the base business case assumptions and evaluating the influence on the Project Net Present Value

2.1.2 Pilot Business Case Analysis for Digital Infrastructure

The first major objective of the Pilot Business Case Analysis for Digital Infrastructure [9] is to provide additional research to address concerns associated with the potential high implementation costs of plant I&C upgrades. Reference 9 describes the application of the BCA methodology from [2] on an expanded set of safety-related and non-safety I&C digital upgrades envisioned for implementation at the research target plant for this research (CPNPP). CPNPP is a Pressurized Water Reactor (PWR). The Owner of this research target plant is in the early stages of pursuing a more comprehensive set of digital upgrades. Reference [9] identifies potential upgrades of 22 current safety and non-safety related I&C subsystems by migrating their function or interfacing equipment that performs their function into either a safety-related digital platform or a non-safety distributed control system (DCS) platform. This two-platform solution is being pursued in order to consolidate respective safety-related and non-safety related functions as presented in LWRS research report INL/EXT-21-64580, *Digital Infrastructure Migration Framework* [6].

A particular innovation in this BCA is estimating the opportunity cost of lost generation revenue from equipment reliability events due to the failure of current I&C components for long-term operations. A crucial benefit of system modernization and digitalization is the prevention of unplanned forced outages resulting from the failure of aging and obsolete safety and non-safety equipment which leads to lost generation revenue. This is an important addition to the BCA developed and used for the LGS safety-related I&C upgrades [2].

The resultant BCA provides a Net Present Value (NPV) for the upgrade project and an Internal Rate of Return (IRR). The detailed BCA for applying the two-platform I&C solution from Reference [6] provides a compelling case for these digital I&C upgrades. Table 2 from Reference summarizes the order of magnitude, non-proprietary results of this BCA for the baseline case for 30 years and 50 years of continued operations.

Table 2. Net present value of I&C digital modernizations for 30 years and 50 years.

Scenario Title	Payback Period	NPV	IRR
Baseline (30 Years of Continued Operation)	17.8 years	$74M	8.1%
Baseline (50 Years of Continued Operations)	17.8 years	$685M	11.8%

2.1.3 Conclusions from Instrumentation and Control Business Case Analyses

The process developed for performing BCAs on digital I&C systems has been fully developed and demonstrated for two separate upgrades. One of the representative plants was a BWR and the other was a PWR. Both business cases are based upon leveraging digital I&C safety systems for which a topical report has been previously reviewed by the NRC. The second business case analysis also added significant non-safety I&C upgrade scope and consideration of potential lost generation which is forecasted to occur if existing I&C systems are not modernized. The positive NPV research results of the BCAs captured in [2 -LGS] and {9-CPNPP) provide a foundation of economic support for digital I&C upgrades where continued operation of existing plants that implement them expect to remain in operation for an additional 15-20 years. Both BCAs are publicly available to industry to enable the performance of similar activities by utilities for planned safety-related and non-safety digital upgrades.

2.2 Integrated Operations for Nuclear Work Reduction Opportunities

The second major objective of Reference [9] was to lay the foundation to expand the use of the BCA methodology and associated tools developed as described in Reference [2] to a larger scope of digital upgrades beyond I&C, in order to affect a larger digital transformation of a nuclear plant described in Reference [6]. This effort is guided by the Integrated Operations for Nuclear (ION) research as summarized in the following two LWRS research reports:

- INL/EXT-21-64134, *Process for Significant Nuclear Work Function Innovation Based on Integrated Operations Concepts* [7], and
- INL/RPT-22-68671, *Integrated Operations for Nuclear Business Operation Model Analysis and Industry Validation* [8].

Reference [7] captures WROs identified by utilizing a top-down method based upon a modernized concept of operations as shown in Figure 5 above. Reference [7] describes the ION model, identifies 37 WROs derived from applying it, and demonstrates a high-level approach to implement these WROs to drive operation cost reductions. As was presented in Section 11 of Reference [9], workshops with the Reference Plant Owner were held to determine which ION WROs were considered to have the most potential for future modernization initiatives.

The values presented in Table 3 below from Reference [9] are representative of costs associated with a generic, two-unit PWR, known in this report as the “Representative Plant.” These results have been presented to the Reference Plant Owner and were accepted as a value-add.

Table 3. Net present values for priority WROs as applied to reference plant [9]

<table>
<tr><th>Work Reduction Opportunity Category</th><th>Base Work Reduction Opportunities for Demonstration</th><th>Net Present Value (NPV) (20 years)</th><th>Probability of Positive NPV</th></tr>
<tr><td rowspan="2">Mobile Worker Technology</td><td>Automated Troubleshooting</td><td rowspan="2">$17.3M</td><td rowspan="2">100%</td></tr>
<tr><td>Remote Plant Support/Remote Assistance</td></tr>
<tr><td>Condition Based Monitoring</td><td>Implement Condition-Based Maintenance</td><td>$37.9M</td><td>95%</td></tr>
<tr><td>Software Application Assisted Business Processes</td><td>Automated Planning and Scheduling</td><td>$5.9M</td><td>75%</td></tr>
<tr><td rowspan="4">Advanced Training Technology</td><td>Operations Training Modernization</td><td rowspan="4">$5.9M</td><td rowspan="4">87%</td></tr>
<tr><td>Technical Training Modernization</td></tr>
<tr><td>General Training Modernization</td></tr>
<tr><td>Training Records Modernization</td></tr>
<tr><td colspan="2">TOTAL</td><td>$67M</td><td>88%</td></tr>
</table>

3. DETAILED WORK REDUCTION OPPORTUNITY DEMONSTRATION STRATEGY

This document leverages the priority ION WROs as identified in Table 3 from Reference [9] as a starting point for a specific WRO demonstration strategy. This demonstration strategy will be leveraged by planned future research to more fully mature the process to identify and leverage specific and available technologies and implementation techniques of the four representative WROs as well as additional ION Generation I WROs as resources allow. This WRO maturation is also intended to demonstrate sufficient process methods to produce technical and business case information to enable a pilot utility to approve specific WRO related project(s) for implementation. This will demonstrate to industry a path forward to realize projected WRO implementation savings.

A comprehensive table has been created to help identify, organize, capture, and relate specific information concerning WRO demonstration. This table is captured as Appendix A to this document. This table is written in a way to assist the user in crystallizing their understanding of a WRO with respect to:

1. The "current state" attributes and characteristics which describe how work performed within the WRO scope is accomplished now, and
2. The specific "new state" attributes with regard to each WRO that will facilitate its implementation.

To initiate this effort, the fields currently provided in Appendix A for each WRO evaluated for this demonstration are briefly summarized below.

3.1 Current State

- **Existing Activities:** Identifies specific activities currently being performed in the plant that are enveloped by the identified WRO.
- **Labor/skill Resources Utilized:** Identify specific labor resources by budget owner and position/skill type that are involved in accomplishing existing activities. Identifying the budget owner is important because as part of WRO implementation budgets may shift from one owner (e.g., a labor center) to another (e.g., the IT organization).
- **Labor Resource Budget to Perform Existing Activities:** Self-explanatory. This is identified when performing the business case.
- **Existing Enabling Tool/Application:** Identify specific tools currently used within the envelope of the envisioned WRO opportunity. This should include any current software applications used, any special equipment needed (e.g., maintenance & test equipment, computer resources), procedures, and particular skills of craft.
- **Tool/Application/Skill Budget Owner:** Identify the budget owner for the existing enabling tools and applications. Identifying the budget owner is important because as part of WRO implementation, budgets may shift from one owner (e.g., maintenance) to another (e.g., the IT organization).
- **Tool/Application Costs (yearly cost):** Self-explanatory. This is identified when performing the business case.
- **Current Yearly Costs (total):** This is the sum of yearly tool/application costs and the labor resource budget for personnel to use the tool to perform its existing functions.

- **Current DI Tool Location on Existing Digital Infrastructure:** It is presupposed that nuclear utilities may have portions of the DI concept already installed as depicted in Figure 2, although they are not likely fully integrated as depicted in Figure 2. Identification of existing DA&A applications allows for evaluation of their current capabilities/usage and insights into how applications may be either leveraged going forward or identified for replacement with others that are more capable, more cost effective, and/or provided with better long-term lifecycle support.
- **DI Level:** Identifies where in the existing DI at a particular plant where the existing DA&A application resides.

3.2 New State

- **New/Augmented Function:** A description of the necessary new or augmented function that is to be provided to enable the identified WRO.
- **Enabling DA&A Application:** Identification of specific DA&A applications which can provide (and ultimately which application(s) are selected for) implementation by a utility.
- **Application Owner (Budget Source):** The organization that will provide the budget to purchase, deploy, and support the DA&A applications to achieve the New State.
- **Enabling DI Domain location of DA&A Application:** This is intended to identify in which DI domain as depicted in Figure 2 of the DI the application is expected to reside, namely:
    - The digital safety-related I&C platform – Purdue Model Level 0-2
    - The non-safety DCS – Purdue Model Level 0-3
    - The Emergency Preparedness Network (EP-Net) – Purdue Model Level 3.5
    - The Corporate Business Network – Purdue Model Level 4 (or higher).
- **DI Level(s):** Identifies where in the New State DI at a particular plant where the DA&A application resides that is used to enable the WRO (associated with DA&A application DI location as listed in the bullet directly above.
- **DI Features Required:** Identifies specific DI capabilities that are necessary to enable the WRO.
- **Policy/Procedure Challenges:** Identifies specific areas where existing policies and procedures may have to be examined/modified based upon the reallocation of workload as enabled by technology. It is expected that both policy (governance) and procedures (processes) will need to be modified to fully realize WROs.
- **Impacts Regulatory or Industry Commitments:** Reallocation of workload to digital equipment (e.g., automation, I&C self-diagnostics, condition-based diagnostic and prognostic DA&A applications, etc.) may directly impact existing methods and techniques described in NRC licensing, other statutory requirements, or industry commitments (e.g., INPO). Implementation of WROs may require modifications in these areas (e.g., elimination of surveillances, changing of maintenance activities to be risk-informed instead of calendar-based, etc.).
- **HSIs (enabled by HTI):** Identification of where digital HSIs should be located and how they should be populated to best enable remaining personnel to optimally supervise the implementation of the WRO for maximum benefit.
- **Remote Support Capability:** Identification of potential remote support capabilities enabled by the implementation of the WRO using digital technologies. These could include, but are not limited to individual remote resource support, remote support provided by a centralized utility digital resource pool, or leveraging remote digital system vendor capabilities and resources.

- **Implementation Costs:** Identification of the costs to procure and implement the necessary DI modifications to host the necessary DA&A application(s) as well as the cost to procure and implement the application(s) themselves. Initial training costs would likely also be captured here. These are expected to be capital costs.
- **Expected Yearly Costs:** Identification of the costs necessary to maintain the portions of the DI to host DA&A applications and to maintain those applications themselves. This would include, but are not limited to yearly software licensing and vendor support fees, continuing training, etc.
- **Expected Yearly Savings:** Self-explanatory. Obtained by comparing current state yearly costs to new state yearly costs.
- **Payback Period:** The time period in years where the net cost reductions realized from WRO implementation account for the WRO investment such that the NPV of the investment is zero.
- **Relationships to/Synergy with other WROs:** This identifies by number and title where there may be specific relationships to other WROs from the list of ION identified WROs captured in Reference [7], Section 5.
- **Relationship/Synergy Details:** A key principle to note is the intended integrated nature of ION WRO implementation. In most cases in industry today, individual plant maintenance and improvement efforts are identified, analyzed, approved, developed, and applied as specific point solutions within the existing labor-centric processes described in Section 1.2.1. Projects created following this process are typically tightly bounded in the areas of scope, schedule and cost following industry project management processes. Approval to implement individual WROs in this manner is typically driven by the scoring of WRO following a specific set of criteria (e.g., the risk to safety, the risk to generation, cost, difficulty to implement, project costs and payback, impact to outage planning, etc.). Projects that score the highest are then prioritized for implementation based on the available budget.
- Appendix A is an effort to put into practice the advanced concept of operations as identified in Section 1.2.2. Digitally enabled WRO implementation is best executed within a coordinated strategic program of related projects. In this way, investments made in one area of digital modernization can be leveraged by other areas to achieve significant additional WRO benefits in other areas. This concept is more fully developed in the subsections below, which provide illustrative examples of this synergy.

Appendix A is an initial version intended to be a starting point to be used to both guide the identification of and ultimately summarize the results of WRO demonstration efforts for utilities that implement this strategy. The information provided in Appendix A at this point is to aid in identifying specific information that focuses on both the needed capabilities and specific methods to implement them. Information for individual line items in Appendix A are also intended to generally align from left to right (as much as it is practicable) within the table. Because of the diversity of the scope of WROs, it is challenging to completely standardize the method by which information is quantified and captured with a limited number of table fields.

It is intended that the content and format of Appendix A will be leveraged and refined during its use in planned follow-on research to occur in FY 2024.

4. ILLUSTRATIVE EXAMPLE OF AN ION GEN 1 PLANTWIDE INTEGRATED SOLUTION WITH SELECT WORK REDUCTION OPPORTUNITIES

4.1 Digital Instrumentation and Control Upgrades

The digital I&C upgrade BCAs, References [2] and [9], include significant cost savings enabled by leveraging the capabilities of the envisioned two-platform solution (one safety-related I&C platform and a non-safety DCS) as more completely described in the DI Migration Framework [6]. Achieving these savings requires a concerted effort to both understand and apply these available capabilities in concert with other technology deployments and procedural and governance changes.

Material benefits including addressing obsolescence as well as avoidance of lost generation benefits identified in Sections 2.4.2 and 2.4.3 of Reference [9) are primarily based on fixed characteristics of the new safety-related digital I&C platform and the non-safety DCS envisioned to be installed and the decommissioning of legacy equipment. These also tend to I&C minimize single-point failures, minimize plant upsets, improve plant performance with regard to operating margins and permit power uprates.

Section 2.4.1 of Reference [9], identifies two specific WROs with benefits enabled by digital I&C upgrades. These are developed in the subsections below along with associated entries in Attachment A to provide direction for WRO demonstration. These presentations here and in Attachment A are intended to be complementary. Some information may occur in both places while other information may not.

4.1.1 Automated Troubleshooting (Work Reduction Opportunity MW-01)

Modern digital I&C systems offer self-diagnostics and automated troubleshooting down to the line replaceable unit (LRU). These capabilities are typically provided within the digital I&C systems themselves as an included feature. Several digital platforms approved for safety I&C use by the NRC include advanced fault detection and self-diagnostics features to minimize O&M costs when compared to current analog systems. The NRC has approved the use of such features to reduce/eliminate Technical Specification surveillance requirements for safety-related digital equipment in new plant designs (e.g., the Westinghouse AP1000® Common Qualified Platform as described in Reference [13]). These features, coupled with proper system design, identify failures down to the affected LRU, which can then be replaced while the plant remains online (for redundant design implementations), again improving system and plant reliability and availability. All modern digital non-safety DCS platforms have such capabilities resident on the associated platform. By design, both digital platforms also eliminate analog equipment calibrations for the equipment they replace. Self-diagnostics, automated troubleshooting, and calibration and surveillance workload reductions are addressed in detail under the MW-01 entry in Appendix A.

4.1.2 Remote Plant Support & Troubleshooting (Work Reduction Opportunity MW-02)

4.1.2.1 Restoration of I&C Systems Based on Self-Diagnostics

Many I&C systems also have the capability to transmit diagnostic and automated troubleshooting results unidirectionally to other networks to facilitate remote support. This capability is not something that would reveal itself when performing “like-for-like” system replacements following the current plant concept of operations. This capability offers the opportunity to provide a myriad of additional WRO I&C upgrade benefits. Such I&C benefits include the capability for local utility personnel to engage with remote resources that are provided with I&C system data in near-real time (within seconds or minutes) to help aid in zeroing in on a problem and resolving it. This also allows for consolidation of utility I&C digital support resources to a centralized I&C support capability which can be leveraged on a demand basis to reduce overall utility workload when more than one site is involved. Finally, many I&C vendors offer on-demand remote support that can be contracted as a fee-for-service which may be leveraged to further minimize O&M costs.

When developing this item within Appendix A, it became apparent that other “run the business” activities associated with the restoration of I&C systems could leverage the digital I&C self-diagnostic information. These additional benefits tend to relate to other WROs identified in Reference [8], some of which are captured in Appendix A.

When developing this item within Appendix A, it became apparent that similar transmission of digital data from the increasing set of DA&A applications could also be leveraged for similar purposes. For this reason, a column for “remote support capability” has been included in Appendix A to identify such opportunities for all analyzed WROs.

4.1.2.2 Remote General Plant Support

As discussed in Section 5.6.2 of Reference [7], the DI also supports general remote plant support. Remote plant support in this sense leverages digital remote collaboration technologies and corporate business network connectivity to allow a nuclear plant to use central or contracted resources for this specialty expertise on an on-demand basis. Further, remote collaboration technologies enable remote parties to effectively interface with the station activities without having to go into restricted spaces or travel to the sites and experience the delays that travel would involve. Digital technologies that generally support remote plant support are identified in Appendix A. These include, but are not limited to, the use of portable wireless devices with high-definition, bi-directional video and audible capability to provide virtual presence of remote workers. This is also augmented by the increasing availability of remote access to live plant I&C data and direct access to business network data and site electronic data and processing tools.

Cost savings enabled by such arrangements are much more than the reduction in direct time charges enabled by remote, on-demand leveraging of experts. It is also the avoided cost of maintaining full-time resources for specialty expertise, including recruiting, hiring, training, non-productive time, maintaining backup for when a resource is unavailable, and repeating these costs whenever turnover in these positions occur. Remote plant support can provide a station that has access to a much more experienced expert who is involved in a variety of issues across the industry and not just what happens at one station or one utility fleet. Using such remote workers also eliminates the overhead costs (e.g., facilities) to support a larger, dispersed, and redundant resource pool.

The ability to gather, analyze, and distribute the vast amount of available made available by implementing a comprehensive DI greatly enables other WROs including remote support and automated work. This creates a significant overlap between individual WRO scopes. If this overlap is not managed, efficiencies may be lost. Properly managing the overlap, on the other hand, can be an efficiency multiplier. This is discussed more in Section 4.1.3

4.1.3 Digital I&C Upgrades – Synergy with Other Work Reduction Opportunities and Enabler of Remote Support and Automated Work

Modern digital I&C systems can capture and digitally transmit both field-sensed and calculated values for process variables. Non-safety I&C systems also have the capability to time stamp I&C digital sensor and calculated process variables that it either creates or that are sent to it by other digital systems (such as the safety-related digital I&C platform). This data collection, time stamping, and storage occur within DI Purdue Model Levels 1 through 3 as shown in Figure 2. This directly supports I&C modernization and enhanced I&C capabilities as discussed above. such as automatic data logging and trending, automation of control functions, and improved I&C HSIs.

As more and more I&C functions are migrated to either the safety-related digital I&C platform or the non-safety DCS more and more time-stamped I&C field sensed and process variable data can be captured. This is largely just a bi-product of I&C digitalization. But, this data can also be transmitted unidirectionally out of the I&C systems to higher levels of the DI just as I&C diagnostic and troubleshooting information can be as discussed in Section 4.1.2.1. Forwarding of all this information in a way that affords ready data access (through consistent data formatting or use of application programming interfaces (APIs) provides enabling capabilities for other identified WRO opportunities implemented at other levels of the DI with minimal additional cost. This is particularly true for enabling WROs resident at Levels 3.5 (EP-Net) and 4 (Corporate Business Network) by providing digital data that is not currently available from analog or legacy standalone digital I&C systems not connected to the DI. Other digital data sources at Levels 3.5 and Level 4 can also be integrated into a plant-wide digital data repository. Such data availability supports a synergy of WRO technologies where the result of integration can be much more than if each WRO was implemented independently.

To capture these and similar opportunities for synergy:

- Columns for "Relationships to/Synergy with other WROs" and "Relationship/Synergy Details have been included in Appendix A.
- Attributes such as time stamping of I&C digital data to a synchronized, high-accuracy time source have been added to the "DI Features Required" field in Appendix A to enable these synergies.

More with regard to capitalizing on these synergies is presented in Sections 4.2 and 0.

4.2 Implement Condition Based Monitoring (CB-02)

Condition Based Monitoring (CBM) is intended to identify changes in asset performance that indicate a degraded condition or impending failure. CBM is enabled by two fundamental capabilities. The first is the availability of quality data which can be evaluated to determine the condition of monitored assets. The second is DA&A applications which can analyze the data to determine the state of those assets.

The DI provides two direct methods to obtain live data for analysis. Section 4.1.3 describes the increasing availability of digital I&C field sensor data as more I&C functions are migrated to the digital safety-related I&C platform and the non-safety DCS. The corporate business network at Purdue Model Level 4 can also be leveraged to collect additional digitized field sensor data to augment that provided by the I&C systems. This is typically accomplished through the use of either wireless or wired sensors. Power must be provided to both types (either self-powered or connected to a power source). Wireless sensors are typically preferred to minimize installation costs. Wireless sensor connectivity is shown at the top-left of Figure 2. The intent is to leverage required I&C data used for plant operation as much as possible as part of CBM and to supplement it with corporate business network gathered sensor data as necessary. I&C data communications from Purdue Model Network Levels 2 or 3 to the corporate data network at Network Level 4 must follow associated cybersecurity rules.

To best support CBM capabilities DA&A applications need to perform two types of functions. First, aggregation and correlation of field-sensed digital information is necessary. Aggregation can be accomplished through different types of commercially available software (e.g., Areva PI System or similar). Methods to synchronize field data from the two field sources to a standard time source as part of the DI for data correlation must also be addressed along with data storage and retrieval requirements.

With aggregated and correlated data available, DA&A applications can be used to diagnose off-normal plant conditions. Such capabilities are already in use in industry facilities such as the Luminant Power Operations Center (https://www.luminant.com/poc/). Additionally, diagnostic and prognostic DA&A applications are providing increasingly powerful capabilities to support CBM. The challenge to be addressed during the execution of this WRO demonstration strategy is to define specific methods to implement CBM over time to enable CB-02 WRO identified savings. Attachment A is intended to aid in identifying not only specific CBM related digital upgrade needs, but also to maximize the synergy of other digital upgrades to produce an aggregate solution that provides higher levels of CBM functionality and the lowest aggregate cost.

4.3 Automated Planning and Scheduling (PR-01)

Scheduling the performance of a typical corrective work package, including the assignment of craft personnel to execute it requires a significant amount of effort. This activity is currently accomplished manually by workers across several work groups following multiple processes using several different standalone software applications. The current manual process requires about 4 hours per corrective work order to schedule across several work management and maintenance resources. Involved resource types include schedulers, workgroup coordinators from the various maintenance shops, planners, craft tradesmen and craft supervisors.

The development of artificial intelligence (AI) software which integrates the capabilities provided by applications such as Microsoft Azure or Hyland's Alfresco process automation software in conjunction with a work management platform such as IBM's Maximo can significantly reduce the time it takes for nuclear power plant resources to schedule performance of a corrective work order.

EPRI has published a business case on the application of this AI software tool in their paper "Nuclear Plant Modernization Business Case: Business Process Automation for Online Work Management", [14]. The business case is based upon the application of the proposed end-to-end work management tool which automates seven work management steps for scheduling an online corrective work order. These include:

1. Creating the work request

   The proposed AI software helps to create work requests in the work management software by identifying the need for a corrective work order. This is accomplished by linking to the corrective action database. Secondly, the software helps to populate fields in the work request that are critical to complete, such as, the system or component that is broken, location, date/time found, etc. Finally, the software helps to assign a priority to addressing the work order based on the system/component and the description of the fix. This would assign a priority level such as priority 1, 2 or 3.

2. Screening the work request

   In this step of automation, the AI software will validate the fields in the work request and confirm if any details that the user may have omitted are flagged to those fields that need to be entered to prepare it for the next step. The AI software will then look across the current online schedule and identify if there are any open work orders on that system/component that this work request can be bundled into the work window. Finally, the software will help to identify any special requirements, based on past work requests or work orders on this system/part via notes or fields.

3. Creating the work order

   In this step, the AI software converts the work request and creates the work order in the work management software system (e.g., Maximo) and copies the appropriate fields from the work request to the work order and outlines a series of tasks for the corrective work order. The Maximo software would assign it a number once the work order is created in the system. The AI software would populate the work scope based on the work order requestion and looking into past corrective work orders on the same part/component/system. Finally, the AI software would identify the appropriate supporting documents including procedures and drawings that would be needed for craft personnel to execute the work orders.

4. Initial scheduling of the work order

   In this step, the AI software would schedule the work order in the system for the appropriate time window based on when the component/system can be taken out of service. Based on when the work order is scheduled, the software can update plant risk probabilistic risk assessment models to identify any risks to plant operations and flag this to work management and operations to see if the work order needs to be adjusted in the schedule to reduce calculated plant risk. Finally, the AI software will confirm that there are sufficient available craft personnel from the appropriate organizations to perform the scheduled work.

5. Compiling work order package

   In this step, the AI software will compile work order package documents from step 3 directly above, by chapter, in the electronic work package (EWP) software or dynamic work package (DWP) software. The EWP or DWP software will include the suggested documents from various data repository systems (e.g., engineering document management system).

6. Identifying the need for walkdowns

   In this step, the AI work management software will determine the need for a walkdown for the corrective work order and create a work order task for the assigned craft personnel. Finally, the AI software will schedule the walkdown based on the optimal time for the craft and how many weeks prior to ensure the right parts to execute the work order.

7. Final scheduling of the work order - validating skills and qualifications

   In this step, the AI work management software will confirm via a qualification database that the resources assigned have the necessary qualifications and will be current at the time when the work order is scheduled. It will also identify the need for specific training for any resources assigned to execute the work order.

The application of these software tools can significantly reduce workload for schedulers, work group coordinators in maintenance, cycle planners, planners, and supervisors. Additionally, the application of these tools can reduce material spend by using operating experience from the last time a corrective maintenance work order was executed on this system or equipment to ensure the parts taken out to the field are accurate, potentially reducing the need for extra parts to be ordered. Finally, the implementation of these software tools enables the ability of a fleet of nuclear power plants to centralize work management positions that have historically not been considered for centralization and thereby reducing the need for resources physically located at the nuclear power plant.

The business case results indicated a $10.3M NPV savings over 10 years for a representative dual-unit nuclear power plant.

4.4 Emergency Preparedness Digital Upgrades (New)

As mentioned in Section 4.1.3, field sensed and calculated values for process variables from I&C systems can also be forwarded to the EP-Net at DI Purdue Model Level 3.5 as shown in Figure 2. This capability must be unidirectional to address cybersecurity per 10 CFR 73.54, "Protection of Digital Computer and Communication Systems and Networks." [15] while leveraging the guidance in Regulatory Guide 5.71 [10]. This synergy enables EP facilities by providing them with direct, read-only access to all available digital I&C data that is available in the plant MCR. This enables MCR HSIs to be directly replicated in the EP facilities to aid EP coordination and communication. Custom HSIs can also be developed for EP facilities by combining plant I&C data with other EP digital data sources to better support overall EP response from the local operations support center (OSC) and technical support center (TSC) as well as the remote Emergency Operations Facility (EOF). This directly enables emergency response capability improvements.

To support the functioning of the EOF, an emergency response organization (ERO) must be identified, trained, and on-call 24/7 to respond to a potential emergency event. DI integration can provide not only expansive enhancements mentioned above for the OSC and TSC in the EOF, but also enable those features (particularly related to the EOF) to be re-located and consolidated by utilities. This relocation and consolidation has already been achieved by several utilities. This reduces facility support burdens and ERO workload. By integrating this within a larger DI as more thoroughly outlined in Section 4.5 of Reference [6], these digital EP upgrades can also be synergized with other digital upgrades and leverage existing Corporate Network resources to provide workload reductions with a lower aggregate cost. With all EP-Net data being available on the Corporate Network, similar enhancements may also be made to Emergency Response Data System (ERDS) connectivity with the NRC.

The creation of digital "glasstop" simulators are also being pursued by multiple utilities to aid in addressing MCR HFE efforts associated with digital I&C upgrades, and to aid in operator training. This is discussed in more detail in Section 4.5.1.2. This integrated, digital, EP-Net solution tied to a glasstop simulator capability magnifies the ability to improve capabilities across the entire spectrum of emergency response. One of the many DI synergies that can be leveraged for WRO implementation is the potential use of the glasstop simulator in conjunction with EOF HSIs to enable more comprehensive and realistic emergency preparedness training and evaluated drills which could be performed with reduced site involvement, impact, and associated costs. This EP-Net technology could potentially be shared with local and state agencies to allow for enhanced capabilities at a cost that is lower than that expended to sustain existing facility capabilities.

Training to use these capabilities would be best integrated into advanced training as described in Section 4.5.3.2.

Attachment A is intended to aid in the effort through its use to identify and maximize the synergy of other digital upgrades and to identify and select other necessary technologies to produce an optimized EP-Net solution. This solution is intended to provide the required levels of EP support functionality and the lowest aggregate cost.

4.5 Advanced Training

With the projection of long-term existing light water nuclear fleet operations, the need for a proficient workforce has never been more acute. Existing nuclear industry training programs are significant contributors to the high levels of safety and operational performance achieved over the past four decades. However, the conventional industry teaching methods of classroom and laboratory instruction, dynamic learning activities, simulator and on-the-job training, and task performance evaluations have been viewed as stagnant. These legacy approaches to teaching proficiency need to be modernized so that the future workforce sustains its level of performance while delivering it more efficiently. With many experienced workers leaving the workforce, the capability to train a significant number of new personnel needs to be modernized quickly and made more effective before this experience walks out the door. This modernization must be structured in a way that meets the expectations of a younger, and more technologically savvy resource pool.

To accomplish the goal of continuing to train a highly effective workforce for the next 40 years of operations, the industry can leverage existing technology to train the workforce at the same level of quality and effectiveness at a significantly reduced delivery cost. These four training-focused Work Reduction Opportunities (WROs) illustrate how these two goals can be realized. Many of these technologies help implement Institute of Nuclear Operations (INPO) 23-001, “Guidelines for Advancing Teaching and Learning in the Nuclear Power Industry,” Reference [15]

4.5.1 Operations Training Modernization (AT-01)

The operations training group’s workload primarily consists of the six following activities:

1. Conducting classroom training for initial and continuing operators.
2. Conducting training for control room operators on the simulator.
3. Conducting dynamic learning opportunities in a laboratory or test setting for new and experienced operators.
4. Examination preparation, delivery, and grading.
5. Licensed operation selection class.
6. Accreditation program oversight.

The workload modernization in this WRO impacts the first four areas of the operations training group described above.

4.5.1.1 Classroom Training Modernization

Current initial and continuing training delivery methods include a significant portion of classroom instruction and traditional computer-based training (CBT) modules. Traditional CBT modules consist of text-driven PowerPoint slides with sparse multimedia, stock photos, and questions that are academic in nature (e.g., What is an example of a highly explosive material sign?).

Modernization of classroom training focuses on augmenting or replacing much of the classroom instruction content with video-based, scenario-based, real-world examples of nuclear operators performing work, using right and wrong behaviors, with utility-specific procedures as part of the video-based training content. The content can be used to more effectively teach the aspects of operating a nuclear power plant and the concept of why they are making decisions, while imbedding operating experience and the implications of being wrong.

The training content can be delivered via on-demand, in the classroom, or on a structured time via a digitally captured module. The same content can be input into different types of learning modules. The delivery of these modules and/or content can be via a computer, portable device (e.g., phone or tablet), or Virtual Reality (VR)-type headset.

The development of these video-based, scenario-based, digital learning modules will require new software to capture and edit the content as well as an enterprise streaming platform (e.g., Vimeo or Microsoft Stream). Additionally, the organization will need to invest in camera equipment, microphones, and storage for the data of the video learning content. The necessary storage area to capture this content can be quite large, so the organization needs to ensure necessary availability. The most important driver to ensure the utility realizes savings from this modernization is utilization of personnel experienced in the development and maintenance of multimedia training content. These personnel are essential to capture, edit, and assemble the training content most efficiently to maximize its quality and realize the maximum possible level of training delivery workload reductions.

The value of this modernization is realized in the reduction of workload for the training managers, instructors, and clerical staff as well as in the reduction of time spent on learning by learners.

4.5.1.2 Simulator Modernization

Nuclear plant main control room (MCR) operators currently train on a high-fidelity, dynamic, qualified MCR simulator which includes the operating unit's control room panel indications, controls, and annunciator panels. For legacy MCR simulators, plant I&C upgrades with associated HMIs in the control room were implemented in these qualified simulators through custom modifications to replicate the look, feel, and operational characteristics observed in the plant control room. The associated items depicted in red in Figure 8 were modified in the simulator to accomplish this end.

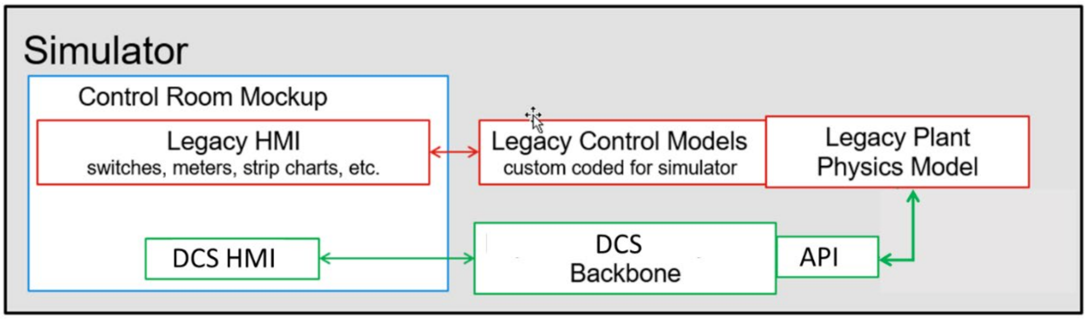

Figure 8. Non-safety I&C DCS integration into the main control room simulator.

Such modifications require significant additional effort, because there was no way to directly incorporate the plant I&C changes into the simulator. Incorporating each of them into the simulator was a unique engineering activity that followed a basic template. The operation and maintenance effort for such a simulator requires a significant amount of labor, including a full-time staff and a configuration control process anytime a modification is made to the control panels of the operating units and systems.

As described in Section 3.2 of "Addressing Nuclear I&C Modernization Through Application of Techniques Employed in Other Industries," [5] it is possible to directly incorporate I&C software for both HSIs and control logic created for digital I&C upgrades for the operating unit into the qualified simulator. This is shown in green in Figure 8. Legacy control models for functions included in the digital I&C upgrade are deleted and replaced with new software code that is created for the plant (without modification). As more and more digital I&C upgrades are performed in the plant following this methodology, the easier it becomes to implement I&C upgrades in the qualified ANSI 3.5 simulator. This also makes the simulator significantly easier to maintain and update. This allows for workload reductions in maintaining the qualified MCR simulator which will increase as more I&C upgrades so implemented are accomplished.

As also discussed in [5], it is possible to create full-scope glasstop simulators. An example is shown in Figure 9.

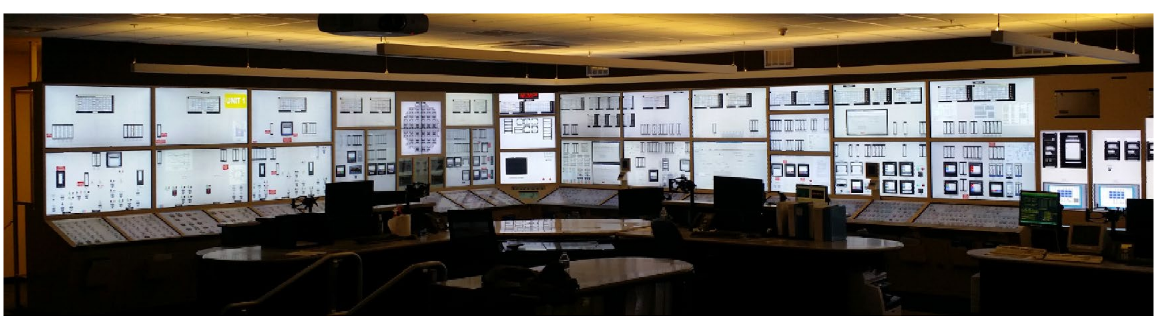

Figure 9. Representative utility nuclear plant glasstop main control room simulator.

These glasstop simulators use a copy of the same plant model, control model, and HSI software used to drive the ANS 3.5 simulator along with pre-developed software renditions of legacy MCR panels. Because of this, the cost associated with creating and maintaining a glasstop simulator is minimized. The capabilities and associated benefits glasstop simulators are increasing being recognized by industry as a value add as further presented below.

Glasstop simulators, similar to what has been developed as shown in Figure 9 and as also available at the Idaho National Laboratory, provide for a host of synergies with other nuclear plant activities and associated WROs. These include:

- Using the glasstop for aid in digital I&C related HSI design and to elicit design feedback from Reactor Operators (ROs) and Senior Reactor Operators (SROs). Procedure changes associated with digital I&C upgrades can also be similarly examined and refined.
- HFE evaluations of HSIs. Glasstop simulators have provided sufficient fidelity to be used for HFE design verification validation of HSIs associated with digital I&C upgrades.
- The ability for nuclear power operators to train on a high fidelity digital" version of the panel boards. This training is different from the credited training performed in qualified ANSI 3.5 training simulator but is still very valuable. The simulator is still fully interactive (with differences in the method of performing physical actuations when compared to the qualified training simulator). It can be used for many other purposes such as walk throughs and familiarization training on HSI and procedures prior to implementation of digital I&C upgrades.
- Use of the glasstop simulator in support of EP drills as discussed in Section 0.
- Use of a centralized fleet glasstop simulator facility that could be leveraged by multiple stations for the purposes above to further reduce costs.

Of course, using a glasstop simulator for formal, credited licensed operator qualification, continuing training, as well as licensed operator examinations would need approval from the NRC. Such an endorsement is possible; however, once digital I&C modernization is undertaken to support long-term operations of the nuclear power plants. Nevertheless, the implementation of a glasstop simulator allows for a significant amount of workload reduction for the training department as well as in other areas when synergies with other WRO implementations are considered.

4.5.1.3 Conducting Dynamic Learning Activities in a Laboratory or Test Setting and Examination Preparation

Modern training technology enables the use of video-based and scenario-based learning modules with operating experience and procedural guidance included within them. Learners can use these modules to become familiar with equipment, settings, and environments that are realistic when compared to the plant environment where they will actually perform work. Feedback from many training leaders across the industry indicates these types of modules will be more cost effective to build and maintain, and learners find them to be more realistic than VR environments. The modules test the skill sets that actually need to be tested instead of dealing with non-value added technology induced challenges such as how to use a hammer in a virtual environment.

One key benefit of these video-based modules is learners will be able to more quickly recognize the environment they are in and decisions they will need to make when being evaluated on examinations or proficiency tests.

This added proficiency helps to reduce training time for line organization instructors and learners.

4.5.2 Technical Training Modernization (AT-02)

The technical training organization's workload primarily consists of four areas listed below. These include:

1. Delivery of training content in the classroom.
2. Teaching in a laboratory or dynamic learning environment, including setup and clean-up.
3. Learner evaluation.
4. Accreditation oversight.

This workload is the responsibility of the managers, instructors, and clerical staff within this organization. The technical training consists of accreditation training programs for the workforce for Maintenance, Chemistry, Radiation Protection, and Engineering.

This work-reduction opportunity reduces or eliminates work for the first three areas of technical training through the implementation of digital technology applications and infrastructure.

4.5.2.1 Classroom Training Modernization

Similar to operations training as described in Section 4.5.1, a significant portion of initial and continuing technical training consists of classroom instruction and traditional CBT modules for initial and continuing training.

Technical training modernization focuses on augmenting or replacing a significant amount of classroom instruction content with video-based, scenario-based examples of situations the technical staff will encounter in the nuclear power plant. This training content will also include right and wrong behaviors and decisions that should be made when interacting with those situations. Additionally, this training content will include utility-specific procedures and operating experience as part of the video-based training content. Such content can be used to more effectively teach the aspects of the nuclear power plant, the concept of making decisions, and the implications of being wrong.

Technical training content can be delivered via on-demand, in the classroom, or on a structured time via a digital module. The same content can be input into different types of learning modules including videos and referred to in any remaining classroom instruction as reference videos. The delivery of these modules and/or content can be via a computer, portable device (e.g., phone or tablet), or VR-type headset typically connected to the Corporate Business Network.

The workload reduction will impact technical trainer managers, instructors, and clerical staff. One issue the nuclear industry is currently dealing with that this effort will help alleviate is the lack of qualified, experienced training instructors and having to rely on subject matter experts (SMEs) from the line organizations (e.g., Chemistry, Maintenance, Radiation Protection).

4.5.2.2 Teaching in a Laboratory or Dynamic Learning Environment – Including Setup and Cleanup

With the introduction of video-based, scenario-based, digital learning modules that include operating experience and procedural guidance, the learners can now become familiar with equipment, settings, and environments they will experience in the plant.

Like training for operations, technical learners will be able to perform more realistic, dynamic learning activities and potentially perform them more expeditiously. Additionally, these training modules can be used as a replacement for the dynamic learning activities that require significant time to set up and tear down, further reducing the workload for the training instructors.

These training modernization activities also help to reduce training time for line organization instructors and learners.

4.5.2.3 Learner Evaluation

With the implementation of video-based, scenario-based, digital training modules, the evaluation of learners by instructors will be reduced because there will be more opportunities to evaluate performance and proficiency directly through the modules. The modules will identify specific questions, topics, decisions, and concepts where learners may need specific help or remediation training. This is in contrast to potentially subjective evaluations by an instructor during a dynamic learning exercise or laboratory activity.

The introduction of specific questions can provide more data on the learner's areas for improvement or knowledge gap and allow for trending easier through the aggregation of data and analytics. Existing learning management systems, such as Cornerstone, have that capability now; however, the instructors need the dynamic learning exercise to be included in a learning management system (LMS) to evaluate the learners.

With the introduction of more dynamic learning modules in the learning management system (LMS), the tracking, trending, remedial training, and evaluation of learners is expected to result in less workload for instructors, managers, and clerical staff in the technical training organization.

4.5.3 General Training Modernization (AT-03)

General training at nuclear power plants primarily consists of all training outside of accredited training programs. This includes topics such as fire brigade training, leadership behaviors and standards, crucial conversations, plant general access, emergency preparedness, etc. It also includes enterprise topics such as cybersecurity awareness, and anti-harassment education. A significant portion of these education topics are delivered in self-study formats such as CBTs that are akin to PowerPoint slides that one views on their own, or timed audio recordings. Sometimes general training topics are delivered via classroom instruction. Additionally, there are some general training topics delivered via practical training such as fire extinguisher usage or how to properly dress-out for entry into radiological areas.

Because most general training topics are delivered via self-study, the workforce associated with preparing, delivering, and tracking general training is significantly less than operations or technical training. However, there are significant opportunities to leverage digital technology to improve general training learning effectiveness while reducing associated workload and costs.

4.5.3.1 Computer-based Training Module Modernization

With the implementation of video-based, scenario-based, digital training modules, the evaluation of learners by instructors will be reduced because there will be more opportunities to evaluate performance and proficiency through the learning modules. The modules will identify specific questions, topics, decisions, and concepts where learners may need specific help or remediation training rather than a potentially subjective evaluation by an instructor during a dynamic learning exercise or laboratory setting.

4.5.3.2 Teaching in a Laboratory or Dynamic Learning Environment – Including Setup and Cleanup

This subject is addressed in a similar manner to laboratory or dynamic learning exercises with operations and technical training as presented in Sections 4.5.1.3 and 4.5.2.2, respectively. With the introduction of video-based, scenario-based learning modules, learners can now become familiar with equipment, settings, and environments they will experience in the plant before they come into them.

Like training for operations and technical learners, general training content will be able to perform more realistic, dynamic learning activities and potentially perform them more expeditiously. Additionally, these training modules can be used as a replacement for the dynamic learning activities that require significant time to set up and tear down, further reducing workload for the training instructors. Applying this type of teaching and learning approach to roles that require consistent training because the workforce is constantly reshuffled, such as emergency response, would be significant for improved proficiency, and improved knowledge transfer.

These general training modernizations help to reduce training time for line organization instructors and learners. Reducing billable time for contractor general training learners, such as training for on-boarding in preparation for supporting a refueling or maintenance outage, directly results in cost reductions. One nuclear operator saw a 5× return in reduction of contractor spending from two modules in support of their outage, without a drop in performance from implementing this type of training modernization.

4.5.4 Training Records Automation (AT-04)

Realizing any workload reduction from this WRO requires integrating digital learning module capabilities within a digital training environment that is capable of automatically tracking acceptable (graded) completion of those modules. This environment also requires the capability to identify and track when training was initially completed and when refresher or re-qualification training is required. Sets of training that together result in the qualification of individuals to perform particular work also needs to be supported including when qualifications were achieved and when they expire. It is expected that this learning management system (LMS) environment will be resident on the Corporate Business Network.

4.5.4.1 Learning Management System Database Integration with Work Scheduling

In order to support digitally automated assistance in scheduling nuclear plant work, the LMS system needs to be integrated with software applications that track both worker availability and qualifications. With the introduction of support software, such as Indevour™, these types of software linkages can be supported. This includes linkage between HR databases, work scheduling software, qualification databases, fatigue databases. The ability of these disparate databases to communicate together through APIs or a shared database enables schedulers to schedule work in the plant while being fully informed with regard to the availability of qualified individuals to execute work.

The more that the LMS system can be integrated with other databases as described directly above, the greater the opportunity to maximize savings for this WRO can be realized.

4.5.4.2 Enabling Performance Improvement of Learners

One key benefit of transitioning to the more expansive use of digital learning modules is the accessibility of additional data on learners, These modules can identify and track learner performance and identify questions or topics where there may be a need for additional training. One approach with training modules used by some non-nuclear utilities is to identify "confidently held misinformation." To understand the value of this particular knowledge deficiency, its identification and tracking in the medical community is illustrative [17]. In the medical community, the most error-prone doctors, physician assistants and nurses are the ones who are confidently wrong in their decision-making for critical tasks. If the nuclear power industry is able to apply this concept to more self-directed digital learning modules, then the training department would be empowered to provide more immediate, tightly bounded, and individualized remedial training to individuals who are identified as falling into this category.

5. CONCLUSION

This strategy will be leveraged by planned future research to more fully mature the process for the identification of specific and available technologies to implement specific WROs within the five categories discussed in Section 4. This strategy will also be used to establish specific implementation techniques for representative candidate technologies for those five WROs categories as well as additional WROs as resources allow. This WRO maturation is intended to produce sufficient technical and business case information to enable a pilot utility to approve specific WRO related project(s) for implementation. This will demonstrate to industry a path forward to realize ION WRO implementation savings.

6. REFERENCES

1. Hunton, P., R. England, et. al. 2020. "Vendor-Independent Design Requirements for a Boiling Water Reactor Safety System Upgrade." INL/EXT-20-61079. Idaho National Laboratory. https://www.osti.gov/biblio/1755891.

2. Hunton, P., S. Lawrie, et. al. 2020. "Business Case Analysis for Digital Safety-Related Instrumentation & Control System Modernizations – as Applied to the Limerick Generating Station." INL/EXT-20-59371. Idaho National Laboratory. https://www.osti.gov/biblio/1660976.

3. Hunton, P., R. England, et. al. 2020. "Safety-Related Instrumentation and Control Pilot Upgrade: Initial Scoping Phase Implementation Report and Lessons Learned." INL/EXT-20-59809. Idaho National Laboratory. https://www.osti.gov/biblio/1668846.

4. Hunton, P., R. England, et. al. 2023. "Safety-Related Instrumentation and Control Upgrade: Conceptual – Detailed Design Phase Report and Lessons Learned." INL/RPT-23-72105. Idaho National Laboratory. https://www.osti.gov/biblio/1983868.

5. Hunton, P., R. England. 2019. "Addressing Nuclear I&C Modernization Through Application of Techniques Employed in Other Industries." INL/EXT-19-55799, Idaho National Laboratory. https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_20014.pdf.

6. Hunton, P., and R. England. 2021. "Digital Infrastructure Migration Framework." INL/EXT-21-64580. Idaho National Laboratory. https://doi.org/10.2172/1822876.

7. Remer, J., K. Thomas, and S. Lawrie, et. al. 2021. "Process for Significant Nuclear Work Function Innovation Based on Integrated Operations Concepts." INL/EXT-21-64134. Idaho National Laboratory. https://lwrs.inl.gov/Advanced%20IIC%20System%20Technologies/ProcessSignificantNuclearWorkFunctionInnovation.pdf.

8. Remer, J., J. Hansen, and S. Lawrie, et. al. 2023. "Integrated Operations for Nuclear Business Operation Model Analysis and Industry Validation." INL/RPT-22-68671 Revision 1, Idaho National Laboratory. https://lwrs.inl.gov/Advanced%20IIC%20System%20Technologies/ION_Operation_Model_Analysis.pdf.

9. Hunton, P., R. England, and S. Lawrie, et. al. 2023. "Pilot Business Case Analysis for Digital Infrastructure." INL/RPT-23-74393. Idaho National Laboraotry.

10. Nuclear Regulatory Commission. 2009. "Cyber Security Programs for Nuclear Facilities," Regulatory Guide 5.71. https://www.nrc.gov/docs/ML0903/ML090340159.pdf.

11. United States Nuclear Regulatory Commission. 10 CFR 50.56. "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants." https://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0065.html.

12. Institute of Nuclear Plant Operations. 2001. AP-913, Rev. 1 "Equipment Reliability Process Description."
13. Merkiel, S. L. 2020. "Common Q Platform and Component Interface Module System Elimination of Technical Specification, Surveillance Requirements." WCAP-18461-NP, Revision 0, Westinghouse. https://www.nrc.gov/docs/ML2002/ML20020A009.pdf.
14. Electric Power Research Institute. 2021. "Nuclear Plant Modernization Business Case: Business Process Automation for Online Work Management." Report number 3002020884.
15. Code of Federal Regulations, Section 10, Part 73.54. 2015. "Protection of Digital Computer and Communication Systems and Networks." https://www.nrc.gov/reading-rm/doc-collections/cfr/part073/part073-0054.html.
16. INPO 23-001, "Guidelines for Advancing Teaching and Learning in the Nuclear Power Industry."
17. Ecker, U. K. H., S. Lewandowsky, J. Cook, et al. 2022. "The psychological drivers of misinformation belief and its resistance to correction." *Nature Reviews Psychology* 1: 13–29. https://doi.org/10.1038/s44159-021-00006-y.

Appendix A

Aggregation of Data Architecture and Analytics Attributes to Enable ION Generation 1 Work Reduction Opportunities

Attachment A

Aggregation of Data Architecture and Analytics Attributes to Enable ION Generation 1 Work Reduction Opportunities

	Current State									New State															
ION Work Reduction Opportunity	Exisiting Activities	Labor/Skill Resources Utilized Owner/Type	Labor Resource Budget to Perform Existing Activities (yearly cost)	Existing Enabling Tool/Application	Existing Tool/Application Owner	Tool/Application Costs (yearly cost)	Current Yearly Costs (total)	Current DI Tool Location on Existing Digital Infrastructure (if enabled electronically)	DI Level	New / Augmented Function	Enabling DA&A Application(s)	Application Owner (Budget Source)	Enabling DA&A Application Location	DI Level(s)	DI Features Required	Policy/Procedure Challenges	Impacts Regulatory or Industry commitments	HSIs (enabled by HTI)	Remote Support Capability	Implementation Costs (Capital)	Expected Yearly Costs (O&M)	Expected Savings Yearly in FY24 Dollars	Payback Period (Years)	Relationships to/Synergy with other WROs (WRO numbers from [Reference X -21 paper] and Digital Modernization	Relationship & Synergy Details
Mobile Worker Technology																									
MW-01: Automated Troubleshooting	**Troubleshooting of Safety-Related I& Systems**	**Owner 1:** Maintenance Technicians **Owner 2:** Maintenance Supervisors **Owner 3:** Component Maintenance Optimization) **Owner 4:** Engineering (inc. Rapid Response) **Owner 5:** Operations **Owner 6:** Strategic/System Engineer - Skill of craft - Operating Experience	(Filled in by utility during development of Business Case)	- Troubleshooting procedures for existing equipment - Maintenance & test equpment - Operating Experience	Paper procedures - Maintenance - Operations - Engineering M&T Equipment: - Maintenance - Locally performed - Centralized Services	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	N/A (legacy systems may have limited capability to self identify system faults)	N/A (stand alone)	Safety-Related I&C Platform Automated Troubleshooting and Self Diagnostics	Application typically included with specific I&C platform. Identify specific capabilities of candidate vendor platform	Capital Cost: O&M Cost: Safety Platform System Owner (Engineering)	Digital Safety Platform	0-2	Built in Diagnostics. Capability to transmit diagnostic information out of system (one way) - System patching	Revise procedures based upon platform capabilities. Expect most surveillance and troubleshooting procedures will be eliminated	Self-diagnostic capabilities must be included in the SER for the Safety-Related Platform to replace existing surveilances	Determine capabilty of platform diagnostic/Health HSIs (both directly on platform as well as in remote facilities.	Identify whether platform diagnostic/health information can be transmitted to a remote resource, a utility centralized facility or vendor for remote support. Identify specific remote support capabilities	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support		MW-02: Remote Plant Support & Troubleshooting CB-02: Condition Based Monitoring DG-01: Maintenance & Surveillance Reduction	
	Troubleshooting of non-Safety-Related I&C Systems	**Owner 1:** Maintenance Technicians **Owner 2:** Maintenance Supervisors **Owner 3:** Component Maintenance Optimization) **Owner 4:** Engineering (inc. Rapid Response) **Owner 5:** Operations **Owner 6:** Strategic/System Engineer - Skill of craft - Operating Experience	(Filled in by utility during development of Business Case)	- Troubleshooting proceedures for existing equipment - Maintenance & test equipment	Paper procedures - Maintenance - Operations - Engineering M&T Equipment: - Maintenance - Locally performed - Centralized Services	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case) (primarily labor costs for troubleshooting legacy equipment	N/A (legacy systems may have limited capability to self identify system faults)	N/A (stand alone)	Non-Safety DCS Automated Troubleshooting and Self Diagnostics	Application typically included with specific I&C platform. Identify specific capabilities of candidate vendor platform	Capital Cost: O&M Cost: Non-safety DCS Owner (Engineering)	Non-Safety DCS Platform	0-3	- Built -in Diagnostics. - Capability to transmit diagnostic information out of system -System patching	Revise procedures based upon platform capabilities. Expect most surveillance and troubleshooting procedures will be eliminated	Expected to be performed under 10CFR50.59 by design.	Determine capabilty of platform diagnostic/Health HSIs (both directly on platform as well as in remote facilities.	Identify specific remote support capability based on platform and how it can be utilized (utility centralized facility or vendor) Base functionality is expected to be provided as part of the digital I&C platform. Vendor support models in other industries support 100% remote vendor support.	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support			
MW-02:Remote Plant Support	**Restoration of I&C Systems (Based on Self Diagnostics)**	**Owner 1:** Maintenance Technicians, peer check, superisor **Owner 2:** System Engineer, and /or **Owner 3:** Operations		- Paper Procedures - Maintenance & test equpment	**Owner X:** Paper procedures **Owner Y:** M&T Equipment			N/A (legacy systems may have limited capability to self identify system faults)	N/A (stand alone)	Automatic identification of failed component to line replaceable unit (LRU). Electronic Procedure/Technical Manual to facilitate replacement of failed LRU.	Vendor provided software applications Vendor provided electronic configuration & replacement instructions Utility locally stored restoration configuration data	Safety Platform System Owner Non-safety DCS Owner Utility/vendor software configuration library	Corporate Business Network? Safety Platform? Non-safety Platform Cyber L4 protected software configuration Library	4 2 2-3 (stand alone - SDOE)	Network hosted procedures & tech manuals	Revise procedures based upon platform capabilities	Evaluation of degree of support which can be provided by I&C vendor in areas of: - Procurement & Config Control - Remote support or direct support to install and configure replacementLRU	Safety Related I&C Platform Status Dashboard/ health screens (on platform) Non-Safety DCS Status Dashboard/ health screens (on platform)	Depending upon the vendor and the ability of their product to provde data remotely, most, if not all restoration activites could be planned and directly supported by remote workers (trained individuals, a utility fleet team, or by the vendor) Remote SR Platform Status dashboard/health screen (remote if available) Remote SR Platform Status dashboard/health screen (remote if available)	Capital Cost: Initial Training	O&M Costs Continuing Training	Labor: Process Support		MW-01: Automated Troubleshooting (New): Automated identification of available inventory/inventory management (New): Automatic requisitioning of components MW-06: Field work preparation and Coordination PR-01: Automated work planning & scheduling AT-02: Technical Training (just in time video delivered with electronic work package)	
	General Plant Support: Local resources directly performing and supporting operations and support tasks (inspections, surveillance, PM, CM, modifications) Functions include observing operations related tasks, peer check, 2nd checker, inspection report, supervision, chemistry activities, etc.	**Owner 1:** Maintenance Technicians, peer check, 2nd checker superisor **Owner 2:** System Engineer, Engineering **Owner 3:** Operations Owner 4: Chemistry Direct observation of equipment condition, direct consultation with system engineer/engineering		Paper based work documents generated by existing software package or other.	Operations System Engineer Engineering Maintenance & Support Org Chemistry, etc.			N/A (legacy systems may have limited capability to self identify system faults) If software tools are currently used, identify where do they reside in the current "digital infrastructure" at the utility.	N/A (stand alone) 4	Mobile Device (laptop, headset tied to computer or thin client) with video/audio capture and presentation capability, digital input. Enhanced ability of personnel to be virtually present to support operations and support tasks including live support of work, observing operations related tasks, peer check, 2nd checker, inspection reporting, supervision, chemistry activities, etc. Ability to collaboratively record results of both local and remotely observed activities (e.g. electronic "smart" work packages)	Operating system that supports access to software application(s) that promote remote support (MS Teams, Zoom, etc.), Interactive electronic procedures, work packages that can be acccessed electronically both locally and remotely. Electronic Procedures & work packages that allow for electronic placekeeping and recording of completion. Access to electronic drawings, instructions.	Business Network Owner (IT) (infrastructure and base applications). Maintenance for work package development. Operations & Maintenance work procedures (Preventive maintenance survellances, visual inspections). Etc.	Mobile Device and Business Network Servers	4	Wireless Network coverage (or wired if required)	Revise procedures based upon platform capabilities.	Challenges with using Business Network resources to support operations and maintenance activities. Largely perception driven.	Laptop HSI or Wearable PC/Headset with audio video capabilities	Voice Communication/Video to communicate with local worker at equipment in plant.	Capital Cost: Initial Training	O&M Costs Continuing Training	Labor: Process Support		Digital I&C Upgrades CB-02: Condition based maintenance MW-06: Field work preparation and Coordination	
Condition Based Monitoring																									
CB-02: Implement Condition-Based Monitoring	Periodic, manual assessments, and surveillances of physical components and structures	**Owner:** Engineering		-Maintenance & test equipment - Paper logs & processes - Applications which capture data and allows for analysis (e.g. Plant Process Computer application captures data than can then be analyzed)	Engineering			Paper logs/ file cabinets Electronic recording of data collected manually typically at specified time intervals Plant Process Computer	4 (for data recorded digitally) 4(plant wireless network if installed 3 & transmit to 4)	Direct electronic collection, time correlation, and efficient and accessable storage of plant/component sensor data for analysis. (Overall plant data historian) Implementation of diagnostic software that detects real-time "off normal" plant or component conditions and alerts personnel prior to exceeding limits that require operator action using station operating procedures. Direct required operator actions are driven by the I&C suite. Implementation of prognostic software that that uses collected plant operational data to monitor/trend equipment performance predictions with regard to availability of continued safe equipment operation. Plant health dashboards that provide management and engineering with actionable diagnostic and prognostic data to enable decisionmaking.	Data Collection, Correlation, and storage engine For I&C and Plant wireless Data) Diagnostic Software Prognostic Software HSI presentation software (ideally standard and consistent with I&C HSI) to present diagonstic and prognostic information	Corporate IT, Digital I&C/OT Engineering, or plant maintenance department.	Corporate Business Network	4	Wireless Network coverage Wireless Sensors for non I&C system data inputs (with associated power sources as necessary) A one-way data path for I&C data coming from Levels 2-3 A standard time source to correllate all data entering the plant historian	Policy/procedure changes to reflect reduction in calendar based maintenance for risk informed condition based maintenance. Policy/procedure changes to reflect roles, responsibiities, and thresholds for centralized/remote notifications and thresholds for immediate local notifications of detected "off normal" performance of monitored equipment Use of condition based / predictive maintenance calculated results by operations (inside and outside of MCR) Data storage requirements. These must be "right sized" to meet need within limits	License Amendment to change surveillance frequencies based upon capabilities of diagnostic and prognostic applications for safety-related equipment at a minimum Discussion with NRC necessary as to how this information can be presnted and leveraged by operations as supplementary information in the Main Control Room and throughout the plant.	Local site dashboards that alert operations and management of diagnostic and prognostic notifications so that prompt action can be taken (after verifying need with direct observation of equipment and/or plant I&C systems).	Significant local workload can be eliminated directly through elimination of manual data collection and analysis. Additional local workload can be eliminated by transfer of active human monitoring to remote support facilities These could include: - a Corporate M&D Center for continuous montioring on live dashboards - Consolidated fleet support facilities for long term trending/analysis - vendor online remote support					Digital I&C upgrades (New): Emergency Preparedness MW-01 through 06: Mobile Worker	
Software Application Assisted Business																									
PR-01 : Automated Planning and Scheduling	Manually scheduling the corrective work orders in online schedule that include the following tasks: - Initial work request - Screen Work Orders - Create Work Order - Schedule Work Order - Compile work package documents - Schedule walkdown - Validate wkills and Qualifications - Assign resources to work order	Scheduler Work Group Coordinator Supervisor Craft Planner	(Filled in by utility during development of Business Case)	Work Management Scheduling Software (e.g., Maximo, SAP) Work package management software (e.g. Dataglance) to manually compile Work Packages to execute work.	Work Management	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Combines AI technology and the work management system to automate incoming CM request screening and work order creation Work identification and screening modules Custom solutions utilized in the work management or plant asset software suite that are used to generate CM and PM work orders. Additinon functions such as creating new condition reports, work requests, engineering change requests, procedure change requests, training requests, routine work tracing items, and assessments may also be supported. Note: Creation of specific documentation (e.g. a work package to execute a work order) is a separate, but related WRO.	Work Management Suite (e.g., ABB's 'Asset Suite', Maximo) Work Planning Auto-Assist / AI (e.g, Microsoft 'Azure' AI software suite) 'Dynamic Work Execution Platform' (e.g., Next Axiom) to automatically compile reference information used to develop a related work package (subject of a separate, but related WRO) Process Automation (e.g., Hyland Alfresco) Failure Mode Tracking Software or System that is able to identify same/similar failures captured in the application(s) A method to either enable aggregation/integration of the above listed applications (via API, bot, or shared data storage, or transfer functions of applications above to an different, available, integrated suite.	Work Management	Corporate Network	4 (or higher)	Desktop computers and mobile devices connected to the plant network Plant communication network available in the protected area Servers to host application and provide necessary storage for data gathering, analysis, and result storage. This could be accomplished in the cloud which would also support remote collaboration.	Work management procedural governance modifications to reflect/enable use of DA&A application features. Application access, configuration control, approval of results (e.g. a scheduled work order) and corporate cybersecurity protection to ensure data integrity from end-to-end	None - Applications reduce workload but industry processes are still followed.	None	Use of the envisioned enabling applications on a fully integrated corporate digital infrastructure enables the capability for planning and scheduling to be accomplished and approved in a centralized utility facility or outsourced to a vendor/contractor. This would allow centralized resource schedule management to more efficently schedule/deploy centralized resources to meet individual plant needs with fewer qualified resources.	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for troubleshooting legacy equipment	AT-04 Training Records Automation PR-02 Computer-Based Procedures PR-04: Campaign Maintenance PR-05: Records Management MW-02: Remote Plant Support MW-06 Filed Work Preparation and Coordination	
(New) Modernize Emergency Preparedness																									

Attachment A

Aggregation of Data Architecture and Analytics Attributes to Enable ION Generation 1 Work Reduction Opportunities

	Current State									New State															
ION Work Reduction Opportunity	Exisiting Activities	Labor/Skill Resources Utilized Owner/Type	Labor Resource Budget to Perform Existing Activities (yearly cost)	Existing Enabling Tool/Application	Existing Tool/Application Owner	Tool/Application Costs (yearly cost)	Current Yearly Costs (total)	Current DI Tool Location on Existing Digital Infrastructure (if enabled electronically)	DI Level	New / Augmented Function	Enabling DA&A Application(s)	Application Owner (Budget Source)	Enabling DA&A Application Location	DI Level(s)	DI Features Required	Policy/Procedure Challenges	Impacts Regulatory or Industry commitments	HSIs (enabled by HTI)	Remote Support Capability	Implementation Costs (Capital)	Expected Yearly Costs (O&M)	Expected Savings Yearly in FY24 Dollars	Payback Period (Years)	Relationships to/Synergy with other WROs (WRO numbers from [Reference X -21 paper] and Digital Modernization	Relationship & Synergy Details
	Current EOF, TSC, and OSC facilities, technologies, and procedures	On call site emergency response personnel. Without a common EOF for a multi-unit utility, a full complement of EOF personnel must be on call for each site.		Existing data and telephone systems Plant Process Computer Existing EP policies and procedure	Site Emergency Preparedness Site Engineering Site IT			Existing wireless data gathering systems and software. Corporate Network Resources Maintenance & test equipment Existing electronic copies of policies, procedures, Paper procedures	3.5 (as required by cyber secuirty rule)	Emergency Preparedness (EP)Network to act as a data historian to Support EP functionality. Consolidation of multiple site-specific EOFs into a consolidated EOF for a fleet of nuclear sites. Time correllation of plant I&C data collected in the Digital Infraxtructure Connectivity of Emergency Preparedness VPN HSI Resources to a Glasstop Simulator to support emergency drills without impacting plant training or plant operation. Permit emergency remote/telework access to EP-Net (e.g. during a pandemic)	EP Net Historian to support emergency facilities with plant information and act as a digital demilitarized zone for I&C data being sent to the Corporate Network Non-Safety DCS Historian correlates safety-related I&C data with non-safety I&C data. Safety-related I&C data is typically sent to the non-safety DCS in a two-platform solution. Glasstop Simulator Historian that replicates Non-safety DCS historian described directly above Ability to grant controlled access of select Corporate Network Computers to the EP-Server	Corporate IT and/or Digital I&C/OT Engineering, EP Department Corporate IT Digital I&C/OT Engineering Corporate IT/Simulator Group Corporate IT/Simulator Group	EP-Network Business Network Non-Safety DCS Time Server (to correlate safety-related I&C data which would be typically sent to the non-safety DCS in a two-platform solution. Glasstop Simulator EP-Net Domain Controller	3.5 4 (virtualized to 3.5) 2-3 4 3.5	A completely logically isolated EP Net Data Server and Demiliterized zone to communicate I&C data to the Corporate Network Plant historian Virtual cyber secure 3.5 network hosted on the Corporate Business Network HSI Thin Clients for EP-Net function. A plant-wide, high accuracy (NTP) time source to correlated I&C and wirelessly connected data Connectivity to the a simulator data historian that replicates plant historian Ability to apply pre-	Revamp policies and procedures to leverage EP Net Capabilities Create policies and procedures to enable a centralized fleet EOF to address such things as - a multi-site, multi-unit event. - activitaition in case of a pandemic - etc. Data retention/storage requirements Proprietary information concerns/restrictions Standardization of wireless devices See above	EOF, TSC, and OSC location changes typically need to be approved by the NRC. Consolidation of multiple, site specific EOFs to a consolidated EOF for a Fleet would need NRC and perhaps state approval. Connectivity between the EP-Net thin clients to the Simulator historian need to consider cybersecurity. Emergency remote access to EP-Net would need to be discussed with NRC	The EOF, TSC, and OSC can be cyber-secure while leveraging the corporate network for communications. All digitized plant I&C data can be presented in these facilities on digital HSI video units (large screens, workstations) to aid in the efficent performance of necessary, facility specific needs. Custom emergency response HSI displays can be developed for presentation on video units as necessary (ideally following the HSI style guide used for the plant). All plant conrol displays on the non-safety DCS can be provided as indication only in the EOF, TSC, and OSC via the EP net and anywhere on the Corporate Business Network. EOF, TSC, and EOF HSIs can be conneted to the Glasstop Simulator Historian to support EP Drills Remote emergency response organization teleworkers have direct access to EP-Net HSIs at home.	Digitized I&C data used for condition-based plant monitoring can be 100% leveraged for support of Emergency Preparedness Facilities. Emergency Support Facilities (particularly the EOF), can be located anywhere in the world or even transferred to a telework functionality should situations arise when this would be necessary. The EP-Net also provides necessary cyber-security isolation of I&C systems when passing I&C data to the Corporate Business Network for enabling condition-based maintenance and other remote support capabilities.					Digital I&C Upgrades Digital Infrastructure Integration MW-02:Remote Plant Support MW-01: Automated Troubleshooting CB-02: Implement Condition Based Monitoring	EP-Net historian and and cyber secure DMZ connectivity os a cornerstone enabler to transmit I&C digital data to enable remote plant support.
Advanced Training	**Training**																								
AT-01: Operations Training Modernization	Classroom content preparation, delivery, improvement	Manager Instructor Clerical SMEs Instructoral technologist	(Filled in by utility during development of Business Case)	PowerPoint Pictures Unfinished videos	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Augment or replace classroom delivery with video-based, scenario based on-demand learning modules, reference use videos of the plant. Portable device access to training materials to support just-in time, on-demand, and assigned learning cap[abilities	**Video capture and Content Creation** that allows editing large frame sizes and advanced effects without rendering. Indluces 360 Video Editing Candidate example applications: - Apple 'Final Cut Pro' Optimized for Mac -Adobe 'Premier Pro' for video editing. Compatible for Windows and MacOS and allows integration of other Adobe applications and use of AI to make editing more efficient **Training Video Delivery** - Web browser or similar - Learning Mangemen System e.g., Articulate/Cornerstone - Video Sharing Platform e.g. Microsoft Stream/VIMEO	Training	Corporate Network	4 (wired and Wireless)	**Video Capture & Content Creation** Cameras (e.g., Sony a7rV) Microphones (e.g., Rode Wireless Go) Camera gimbal (e.g., Ronin RS3) Lights (e.g., Lumecube panel light) Camera tripod (e.g., M anfrotto Element Traveller) 4k monitors for video editing Computers and servers to host applications and store video library content for retrieval. Cloud storage may also be used for storage.	Training governance changes to enable video content capture and development	Maintain SAT and ACAD standards in content	**Training Video Delivery** VR/AR headsets for training delivery (e.g., Oculus, HoloLens) Tablets (multiple models) Desktop computers Ability to control video presentation reqjuired (e.g. handset with headset)	Training content development and management can be centralized and maintained with less workload. This could be managed from a utility fleet location or by a third party.	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for troubleshooting legacy equipment	AT-02: Technical Training Moderinization AT-03: General Training Modernization AT-04: Training Records Modernization	
	Simulator setup, delivery and fidelity configuration changes	Simulator Tech Instructor Instructoral technologist	(Filled in by utility during development of Business Case)	Existing ANSI 3.5 Training Simulator	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	4 (within existing ANSI 3.5 Simulator	4	Digital glass top simulator (e.g., GSE or L3) with touch screen panels	Existing Simulator Models. Existing Glasstop HSI presentation tools I&C HSI Software I&C validated control software simulator models	Training	Connected to DI at Level 4 to allow for data transfers and support of EP Drills.	4*, 3	Servers and storage to support applications	Exam Security Investment Protection (Cybersecurity) Dataflows to enable EP Drills Training governance changes to enable video content capture and development	Guidance on INPO simulator	Glasstop simulator						EP-Net (new)	
	Exam preparation, delivery, evaluation and feedback	Manager Instructor Clerical	(Filled in by utility during development of Business Case)	Exam writing software (e.g., scorpion)	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Augment current written and oral exams with scenario-based videos that can be used in oral or written exams	**Training Video Delivery** - Web browser or similar - Learning Mangemen System e.g., Articulate/Cornerstone - Video Sharing Platform e.g. Microsoft Stream/VIMEO	Training	Corporate Network	4	None	Training governance changes to enable video content capture and development	Maintain SAT and ACAD standards in content	None	Training content development and management can be centralized and maintained with less workload. This could be managed from a utility fleet location or by a third party.					AT-02: Technical Training Moderinization AT-03: General Training Modernization AT-04: Training Records Modernization	
	Licensed operator selection class preparation, delivery and evaluation	Manager Instructor	(Filled in by utility during development of Business Case)	PowerPoint Pictures Unfinished videos	Training			Corporate Business Network	4	Augment current written and oral exams with scenario-based videos that can be used in oral or written exams	**Training Video Delivery** - Web browser or similar - Learning Mangemen System e.g., Articulate/Cornerstone - Video Sharing Platform e.g. Microsoft Stream/VIMEO	Training	Corporate Network	4	None	Training governance changes to enable video content capture, development and delivery	None	None	Training content development and management can be centralized and maintained with less workload. This could be managed from a utility fleet location or by a third party.						
	Accreditation oversight	Manager Instructor	(Filled in by utility during development of Business Case)	MS Tools	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)		N/A	No change															
AT-02: Technical Training Modernization	Classroom content preparation, delivery, improvement	Manager Instructor Clerical Instructoral technologist	(Filled in by utility during development of Business Case)	PowerPoint Pictures Unfinished videos	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Augment or replace classroom delivery with video-based, scenario based on-demand learning modules, reference use videos of the plant. Portable device access to training materials to support just-in time, on-demand, and assigned learning cap[abilities	**Video capture and Content Creation** that allows editing large frame sizes and advanced effects without rendering. Indluces 360 Video Editing Candidate example applications: - Apple 'Final Cut Pro' Optimized for Mac -Adobe 'Premier Pro' for video editing. Compatible for Windows and MacOS and allows integration of other Adobe applications and use of AI to make editing more efficient **Training Video Delivery** - Web browser or similar - Learning Mangemen System e.g., Articulate/Cornerstone - Video Sharing Platform e.g. Microsoft Stream/VIMEO	Training	Corporate Network	4 (wired and Wireless)	**Video Capture & Content Creation** Cameras (e.g., Sony a7rV) Microphones (e.g., Rode Wireless Go) Camera gimbal (e.g., Ronin RS3) Lights (e.g., Lumecube panel light) Camera tripod (e.g., M anfrotto Element Traveller) 4k monitors for video editing Computers and servers to host applications and store video library content for retrieval. Cloud storage may also be used for storage.	Training governance changes to enable video content capture and development	Maintain SAT and ACAD standards in content	**Training Video Delivery** VR/AR headsets for training delivery (e.g., Oculus, HoloLens) Tablets (multiple models) Desktop computers Ability to control video presentation reqjuired (e.g. handset with headset)	Training content development and management can be centralized and maintained with less workload. This could be managed from a utility fleet location or by a third party.	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for troubleshooting legacy equipment	AT-01: Operations Training Modernization AT-03: General Training Modernization AT-04: Training Records Modernization	
	Lab setup & clean-up	Manager Instructor Clerical	(Filled in by utility during development of Business Case)	Dynamic learning building/equipment (e.g., valve lab)	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)		N/A	Potential to eliminate select practical examiniations because of quality of video training (e.g., fire extinguisher)	Video capture and Content Creation that allows editing large frame sizes and advanced effects without rendering. Indluces 360 Video Editing Candidate example applications: - Apple 'Final Cut Pro' Optimized for Mac -Adobe 'Premier Pro' for video editing. Compatible for Windows and MacOS and allows integration of other Adobe applications and use of AI to make editing more efficient Training Video Delivery - Web browser or similar - Learning Mangemen System e.g., Articulate/Cornerstone - Video Sharing Platform e.g. Microsoft Stream/VIMEO	Training	Corporate Network	4	Video Capture & Content Creation Cameras (e.g., Sony a7rV) Microphones (e.g., Rode Wireless Go) Camera gimbal (e.g., Ronin RS3) Lights (e.g., Lumecube panel light) Camera tripod (e.g., M anfrotto Element Traveller) 4k monitors for video editing Computers and servers to host applications and store video library content for retrieval. Cloud storage may also be used for storage.	Training governance changes to enable video content capture and development	Maintain SAT and ACAD standards in content	Training Video Delivery VR/AR headsets for training delivery (e.g., Oculus, HoloLens) Tablets (multiple models) Desktop computers Ability to control video presentation reqjuired (e.g. handset with headset)	Potential to reduce travel time to a lcation to setup the dynamic learning activity	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for troubleshooting legacy equipment		

Attachment A
Aggregation of Data Architecture and Analytics Attributes to Enable ION Generation 1 Work Reduction Opportunities

	Current State									New State															
ION Work Reduction Opportunity	**Exisiting Activities**	**Labor/Skill Resources Utilized Owner/Type**	**Labor Resource Budget to Perform Existing Activities (yearly cost)**	**Existing Enabling Tool/Application**	**Existing Tool/Application Owner**	**Tool/Application Costs (yearly cost)**	**Current Yearly Costs (total)**	**Current DI Tool Location on Existing Digital Infrastructure** (if enabled electronically)	**DI Level**	**New / Augmented Function**	**Enabling DA&A Application(s)**	**Application Owner (Budget Source)**	**Enabling DA&A Application Location**	**DI Level(s)**	**DI Features Required**	**Policy/Procedure Challenges**	**Impacts Regulatory or Industry commitments**	**HSIs (enabled by HTI)**	**Remote Support Capability**	**Implementation Costs (Capital)**	**Expected Yearly Costs (O&M)**	**Expected Savings Yearly in FY24 Dollars**	**Payback Period (Years)**	**Relationships to/Synergy with other WROs (WRO numbers from [Reference X -21 paper] and Digital Modernization**	**Relationship & Synergy Details**
	Lab evaluation and documentation of learners	Manager Instructor Clerical	(Filled in by utility during development of Business Case)	MS Form/Word	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Potential to eliminate select practical examiniations because of quality of video training (e.g., fire extinguisher)	Video capture and Content Creation that allows editing large frame sizes and advanced effects without rendering. Indluces 360 Video Editing Candidate example applications: - Apple 'Final Cut Pro' Optimized for Mac -Adobe 'Premier Pro' for video editing. Compatible for Windows and MacOS and allows integration of other Adobe applications and use of AI to make editing more efficient Training Video Delivery - Web browser or similar - Learning Mangemen System e.g., Articulate/Cornerstone - Video Sharing Platform e.g. Microsoft Stream/VIMEO	Training	Corporate Network	4	Video Capture & Content Creation Cameras (e.g., Sony a7rV) Microphones (e.g., Rode Wireless Go) Camera gimbal (e.g., Ronin RS3) Lights (e.g., Lumecube panel light) Camera tripod (e.g., M anfrotto Element Traveller) 4k monitors for video editing Computers and servers to host applications and store video library content for retrieval. Cloud storage may also be used for storage.	Training governance changes to enable video content capture and development	Maintain SAT and ACAD standards in content	Training Video Delivery VR/AR headsets for training delivery (e.g., Oculus, HoloLens) Tablets (multiple models) Desktop computers Ability to control video presentation reqjuired (e.g. handset with headset)	Potential to evalute learner remotely	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for troubleshooting legacy equipment)		
	Utility CBTs with academic content	Clerical, Instructors (when proctors are required), Contract service with vendors	(Filled in by utility during development of Business Case)	Artciulate	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Modernize CBTs to develop video-based content that tests what should I do in this situation vs. what is the definition of a term. Shorten the duration of the CBTs by focusing on situations that learners will face vs. complaince related content	**Video capture and Content Creation** that allows editing large frame sizes and advanced effects without rendering. Indluces 360 Video Editing Candidate example applications: - Apple 'Final Cut Pro' Optimized for Mac -Adobe 'Premier Pro' for video editing. Compatible for Windows and MacOS and allows integration of other Adobe applications and use of AI to make editing more efficient **Training Video Delivery** - Web browser or similar - Learning Mangemen System e.g., Articulate/Cornerstone - Video Sharing Platform e.g. Microsoft Stream/VIMEO	Training	Corporate Network	4 (wired and Wireless)	**Video Capture & Content Creation** Cameras (e.g., Sony a7rV) Microphones (e.g., Rode Wireless Go) Camera gimbal (e.g., Ronin RS3) Lights (e.g., Lumecube panel light) Camera tripod (e.g., M anfrotto Element Traveller) 4k monitors for video editing Computers and servers to host applications and store video library content for retrieval. Cloud storage may also be used for storage.	Training governance changes to enable video content capture and development	Maintain SAT and ACAD standards in content	**Training Video Delivery** VR/AR headsets for training delivery (e.g., Oculus, HoloLens) Tablets (multiple models) Desktop computers Ability to control video presentation reqjuired (e.g. handset with headset)	Training content development and management can be centralized and maintained with less workload. This could be managed from a utility fleet location or by a third party.	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for troubleshooting legacy equipment)	AT-01: Operations Training Modernization AT-04: Training Records Modernization	
	INPO CBTs with academic content	INPO (Contract service)	(Filled in by utility during development of Business Case)	Nantel	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Modernize CBTs to develop video-based content that tests what should I do in this situation vs. what is the definition of a term. Shorten the duration of the CBTs by focusing on situations that learners will face vs. complaince related content	Video capture and Content Creation that allows editing large frame sizes and advanced effects without rendering. Indluces 360 Video Editing Candidate example applications: - Apple 'Final Cut Pro' Optimized for Mac -Adobe 'Premier Pro' for video editing. Compatible for Windows and MacOS and allows integration of other Adobe applications and use of AI to make editing more efficient Training Video Delivery - Web browser or similar - Learning Mangemen System e.g., Articulate/Cornerstone - Video Sharing Platform e.g. Microsoft Stream/VIMEO	Training	Corporate Network	4 (wired and Wireless)	Video Capture & Content Creation Cameras (e.g., Sony a7rV) Microphones (e.g., Rode Wireless Go) Camera gimbal (e.g., Ronin RS3) Lights (e.g., Lumecube panel light) Camera tripod (e.g., M anfrotto Element Traveller) 4k monitors for video editing Computers and servers to host applications and store video library content for retrieval. Cloud storage may also be used for storage.	Training governance changes to enable video content capture and development	Maintain SAT and ACAD standards in content	Training Video Delivery VR/AR headsets for training delivery (e.g., Oculus, HoloLens) Tablets (multiple models) Desktop computers Ability to control video presentation reqjuired (e.g. handset with headset)	Training content development and management can be centralized and maintained with less workload. This could be managed from a utility fleet location or by a third party.	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for troubleshooting legacy equipment)		
AT-03: General Training Modernization	Enterprise CBTs with academic content	None	(Filled in by utility during development of Business Case)	Articulate	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Modernize CBTs to develop video-based content that tests what should I do in this situation vs. what is the definition of a term. Shorten the duration of the CBTs by focusing on situations that learners will face vs. complaince related content	Video capture and Content Creation that allows editing large frame sizes and advanced effects without rendering. Indluces 360 Video Editing Candidate example applications: - Apple 'Final Cut Pro' Optimized for Mac -Adobe 'Premier Pro' for video editing. Compatible for Windows and MacOS and allows integration of other Adobe applications and use of AI to make editing more efficient Training Video Delivery - Web browser or similar - Learning Mangemen System e.g., Articulate/Cornerstone - Video Sharing Platform e.g. Microsoft Stream/VIMEO	Training	Corporate Network	4 (wired and Wireless)	Video Capture & Content Creation Cameras (e.g., Sony a7rV) Microphones (e.g., Rode Wireless Go) Camera gimbal (e.g., Ronin RS3) Lights (e.g., Lumecube panel light) Camera tripod (e.g., M anfrotto Element Traveller) 4k monitors for video editing Computers and servers to host applications and store video library content for retrieval. Cloud storage may also be used for storage.	Training governance changes to enable video content capture and development	Maintain SAT and ACAD standards in content	Training Video Delivery VR/AR headsets for training delivery (e.g., Oculus, HoloLens) Tablets (multiple models) Desktop computers Ability to control video presentation reqjuired (e.g. handset with headset)	Training content development and management can be centralized and maintained with less workload. This could be managed from a utility fleet location or by a third party.	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for troubleshooting legacy equipment)		
	Practical performance of select tasks by learner(s) to demonstrate understanding of task and proficiency	Clerical, Instructor, Manager or Line SME	(Filled in by utility during development of Business Case)	None	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)		N/A	Potential to group more learners together to perform practical proficiency demonstration with an evaluator if the learning can be done via on-demand	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A							
	Classroom instruction of content	Clerical, Instructor, Manager or Line SME	(Filled in by utility during development of Business Case)	PowerPoint	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Augment or replace classroom delivery with video-based, scenario based on-demand learning modules, reference use videos of the plant. Portable device access to training materials to support just-in time, on-demand, and assigned learning cap[abilities	Video capture and Content Creation that allows editing large frame sizes and advanced effects without rendering. Indluces 360 Video Editing Candidate example applications: - Apple 'Final Cut Pro' Optimized for Mac -Adobe 'Premier Pro' for video editing. Compatible for Windows and MacOS and allows integration of other Adobe applications and use of AI to make editing more efficient Training Video Delivery - Web browser or similar - Learning Mangemen System e.g., Articulate/Cornerstone - Video Sharing Platform e.g. Microsoft Stream/VIMEO	Training	Corporate Network	4 (wired and Wireless)	Video Capture & Content Creation Cameras (e.g., Sony a7rV) Microphones (e.g., Rode Wireless Go) Camera gimbal (e.g., Ronin RS3) Lights (e.g., Lumecube panel light) Camera tripod (e.g., M anfrotto Element Traveller) 4k monitors for video editing Computers and servers to host applications and store video library content for retrieval. Cloud storage may also be used for storage.	Training governance changes to enable video content capture and development	Maintain SAT and ACAD standards in content	Training Video Delivery VR/AR headsets for training delivery (e.g., Oculus, HoloLens) Tablets (multiple models) Desktop computers Ability to control video presentation reqjuired (e.g. handset with headset)	Training content development and management can be centralized and maintained with less workload. This could be managed from a utility fleet location or by a third party.	Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for troubleshooting legacy equipment)	AT-01: Operations Training Modernization AT-04: Training Records Modernization	

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Aggregation of Data Architecture and Analytics Attributes to Enable ION Generation 1 Work Reduction Opportunities

	Current State									New State															
ION Work Reduction Opportunity	Exisiting Activities	Labor/Skill Resources Utilized Owner/Type	Labor Resource Budget to Perform Existing Activities (yearly cost)	Existing Enabling Tool/Application	Existing Tool/Application Owner	Tool/Application Costs (yearly cost)	Current Yearly Costs (total)	Current DI Tool Location on Existing Digital Infrastructure (if enabled electronically)	DI Level	New / Augmented Function	Enabling DA&A Application(s)	Application Owner (Budget Source)	Enabling DA&A Application Location	DI Level(s)	DI Features Required	Policy/Procedure Challenges	Impacts Regulatory or Industry commitments	HSIs (enabled by HTI)	Remote Support Capability	Implementation Costs (Capital)	Expected Yearly Costs (O&M)	Expected Savings Yearly in FY24 Dollars	Payback Period (Years)	Relationships to/Synergy with other WROs (WRO numbers from [Reference X -21 paper] and Digital Modernization	Relationship & Synergy Details
AT-04: Training Records Automation	LMS Database maintenance	Clerical, Instructor	(Filled in by utility during development of Business Case)	Cornerstone	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Link training qualifications with time off scheduling software (e.g., Workday), fatigue rule constraints and with online and outage scheduling software to indentify true available qualified resources	Resource scheduling and constraint visualization software (e.g., Indevour)	IT	Corporate Network	4	Npne	Work Management, Training, HR procedural governance updates	None	None		Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for	AT-01: Operations Training Modernization AT-02: General Technical Training AT-03: General Training Modernization	
	Performance monitoring and trending	Clerical or Program Manager	(Filled in by utility during development of Business Case)	Internal database or Cornerstone	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Create video-based, scenario based training modules with confidently held information concept incorporated and use analytical AI software to identify questions or specific crews where remedial training might be required on an individual basis rather than as a group	AI powered learning on a single platform that places an emphasis on an engaging and social learning experience (e.g., Docebo)	Training	Corporate Network	4	None	Training governance changes to reflect remedial training	None	None		Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for		
	Learner attendance completion of classroom or lab requirements	Clerical or Instructor	(Filled in by utility during development of Business Case)	Cornerstone Internal database	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Create more on-demand learning content and modules in the LMS will reduce the requirement of tracking and reporting learner completion of classroom training	Learning Managmenet System (e.g., Articulate/Cornerstone)	Training	Corporate Network	4	None	Training governance changes to reflect remedial training	None	None		Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for		
	Scheduling coordination for available room	Clerical	(Filled in by utility during development of Business Case)	Cornerstone Internal database	Training	(Filled in by utility during development of Business Case)	(Filled in by utility during development of Business Case)	Corporate Business Network	4	Create more on-demand learning content and modules in the LMS and self scheduling options of fulfilling required continuing training	Resource scheduling and constraint visualization software (e.g., Indevour)	Training	Corporate Network	4	None	Training governance changes to reflect remedial training	None	None		Hardware/Software Initial Training	Software Licensing Fees Application of patches Continuing Training	Labor: Process Support	(Filled in by utility during development of Business Case) (primarily labor costs for		