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Light Water Reactor Sustainability Program

Developing a Roadmap for Total Nuclear Plant Transformation

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ABSTRACT

Commercial nuclear power plants (NPPs) provide emission free, always-on electricity that must be part of the energy mix if industries and businesses in the United States (U.S.) are to remain competitive while enjoying the benefits of a clean environment. Most U.S. NPPs in operation today were licensed using state-of-the-art analog technology of the 1970s. While these systems are well proven and designed with multiple redundant channels, they required extensive manual surveillance and testing procedures to demonstrate their continued functioning. In addition, the lack of automated information on component performance required manual equipment data collection and entry into manual logs and files and time-based preventative maintenance scheduling. All of this adds up to increasing labor costs as the only means to increase plant availability.

The U.S. Department of Energy (DOE) Light Water Reactor Sustainability (LWRS) Program is performing a study to determine how an NPP can fully modernize, improve safety, and improve efficiency enough to make nuclear power competitive with current and future market conditions. The study is a process improvement analysis whereby current operational processes are evaluated to identify where efficiencies and cost-savings can be realized. This report will describe a process that will provide each utility with the tools to evaluate their present state, set goals for where they want to be regarding Operation and Maintenance (O&M) costs, while offering transformative pathways to achieve these improvements. The transformative changes will be divided into 1) work process improvements, 2) technology solutions, and 3) regulatory reform. By applying these pathways in combination, NPPs can achieve the dramatic O&M savings needed to sustain safe and economic operation into the future.

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ACRONYMS

AE	Architect Engineer
BU	Bottom Up
BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
CR	Condition Reports
DOE	U.S. Department of Energy
DNP	Delivering the Nuclear Promise
EBR-I	Experimental Breeder Reactor-I
EPRI	Electric Power Research Institute
FTE	Full Time Equivalent
HFE	Human Factors Engineering
I&C	Instrumentation and Controls
IFE	Institute for Energy Technology
INPO	Institute of Nuclear Power Operations
IT	Information Technology
LWRS	Light Water Reactor Sustainability
NEI	Nuclear Industry Institute
NPP	Nuclear Power Plant
NRC	U.S. Nuclear Regulatory Commission
O&M	Operation and Maintenance
OT	Operational Technology
PRA	Probabilistic Risk Assessment
PWR	Pressurized Water Reactor
R&D	Research and Development
RIS	Regulatory Issue Summary
RPS	Reactor Protection System
SRO	Senior Reactor Operator
TD	Top Down
TMI	Three Mile Island
TPT	Total Plant Transformation
TS	Technical Specification
U.S.	United States
WBL	Work Breakdown Level
WFAT	Work Function Analysis Tool

DEVELOPING A ROADMAP FOR TOTAL NUCLEAR PLANT TRANSFORMATION

1. INTRODUCTION

1.1 Overview

Commercial nuclear power plants (NPPs) provide emission free, always-on electricity that must be part of the energy mix if industries and businesses in the United States (U.S.) are to remain competitive while enjoying the benefits of a clean environment. Most U.S. NPPs in operation today were licensed using state-of-the-art analog technology of the 1970s. While these systems are well proven and designed with multiple redundant channels, they require extensive manual surveillance and testing procedures to demonstrate their continued functioning, resulting in increasing labor costs as the plants strive to maintain or increase availability.

The U.S. Department of Energy (DOE) Light Water Reactor Sustainability (LWRS) Program is performing a study to determine how an NPP can fully modernize, improve safety, and improve efficiency enough to make nuclear power competitive in current and anticipated future market conditions. The study is a process improvement analysis whereby current operational processes are evaluated to identify where efficiencies and cost-savings can be realized.

This study is being prepared in conjunction with a U.S. utility partner to help validate assumptions and demonstrate the process. It is expected that the process documented in this report can be adapted for use by any U.S. utility seeking to modernize its plant and regain its competitive position while actually improving safety and performance. This overall LWRS Transformation effort will be aided by the cooperation and expertise of the Norwegian Institute for Energy Technology (IFE). Over the past twenty years, IFE researchers have contributed considerably to the digitization of the Norwegian oil industry, including implementation of advanced modes of Operation and Maintenance (O&M), resulting in significant reduction of O&M costs for offshore oil platforms. Additionally, Scott Madden, an industry-recognized business analysis leader, will also be assisting the LWRS team by providing insights into business and cost management, peer-to-peer and related industry benchmarking, and organization structure and staffing. Their insights and process changes will be incorporated into the overall transformation analysis effort to help achieve the greatest improvements for the least cost.

1.2 Summary of Process and Deliverables

This study builds upon prior research and development (R&D) performed by LWRS Program researchers. Specifically, LWRS milestone reports written by Thomas and Scarola (2018), Joe, Hanes, and Kovesdi (2018), and Joe and Kovesdi (2018) document previous work to develop a strategy for full nuclear plant modernization. This report builds upon these reports by presenting additional aspects related to improving business processes and streamlining organizations that need to be included in this strategy. Thomas and Scarola (2018) laid down the fundamental conjecture for this work: that without complete digitalization, full nuclear plant modernization is not possible. That is, the nuclear industry needs to transition away from a hybrid analog-digital instrumentation and control (I&C) solution for plant operations to a seamless digital environment or architecture that merges plant systems, processes, and workers. Joe, Hanes, and Kovesdi (2018) added details to this conjecture by elaborating on the core human factors engineering (HFE) aspects (i.e., an HFE program plan and an end state vision) that need to be included in full nuclear plant modernization. Their report also pointed out that these core HFE aspects need to be well-integrated with both 1) a technically defensible approach to migrating the existing, mostly analog I&C infrastructure to a digital I&C infrastructure and 2) a valid business case methodology to cost-justify the modernization activity. That is, the HFE program plan and end state vision for plant modernization need to be developed with both cost and technical feasibility in mind. Joe and Kovesdi

(2018) further elaborated on this point by presenting methods, techniques, and tools that can be used to weigh these factors that affect modernization decisions as a function of their costs to implement relative to their expected benefits.

The collaborative effort described in this report builds upon this past R&D, and will specifically use the program and process expertise available at a utility partner, combined with domain and technology expertise provided by the LWRS Program to perform a Top Down (TD) and Bottom Up (BU) analysis that will deliver an optimized organizational end-state vision. The results of this study will be used to develop the value proposition for NPP Transformation. In addition, this research will leverage the results of both technology readiness and business benchmarking performed by the LWRS Program to map out a plan to transition from the current U.S. fleet operational model to the optimized one. This effort will specifically deliver the following:

- An evaluation process to develop an end state vision for NPP Transformation
- A method to collect as-is plant work process information and compare it to the future state organization
- An organized process to evaluate technology solutions, regulatory changes, and work processes changes with a goal of improving efficiency and reducing O&M costs
- An approach to maintain the safe operation of NPPs that also identifies safety improvements by eliminating low value work and replacing labor-intensive work functions with technology-enabled work methods.

2. BACKGROUND

2.1 History of Commercial Nuclear Power Technology

On December 20, 1951 at 1:23 PM, the Experimental Breeder Reactor-I (EBR-I) at the National Reactor Testing Station in Idaho used nuclear fuel to light four 200-watt lightbulbs. The next day, EBR-I generated an estimated 400 kilowatts, which was enough electricity to provide lighting for the entire building and the adjacent parking lot (Goff, 2019). With this accomplishment, nuclear energy faced a bright future, because EBR-I proved that it was possible to use a nuclear reactor to safely generate useable amounts of electric power (Stacy, 2000). From this accomplishment and others, including the U.S. Navy coming up with the basic design for a nuclear reactor, many saw NPPs as a limitless and economical source of reliable electricity. Once a reactor was built and produced heat, the rest of the plant was just like any other thermal plant in operation at the time. The biggest cost of typical coal, oil, and gas plants of that era was the fuel. Since the cost of fuel for a nuclear reactor was a small percentage of the overall cost compared to other electricity sources, the thinking went that power could be produced for a very low cost; in fact, some suggested that it would be so plentiful that it would be "too cheap to meter".

Once the concept of a commercial scale nuclear generating station was demonstrated at Shippingport, PA, in 1958, the race was on to build NPPs for electricity generation. During this time, the Atomic Energy Commission estimated that over 1000 reactors would be operating in the United States by the year 2000. A variety of designs were proposed, and all the big thermal power plant design firms offered a model employing their own unique features. Companies with no prior power plant design experience jumped into the competition since it appeared that more reactor suppliers would be needed to fill the enormous demand for nuclear reactors.

During the first wave of NPP construction, it became clear that designing and constructing an NPP was more challenging than had been anticipated. Some of the plants on the drawing board were scrapped, and those that were built cost much more than had been estimated. However, once the plants were built, they were operated and maintained in the same way and by the same people that typically worked at the utility owner's fossil plants. Plant availability was not as high as it is now, but since production costs were low and profits were stable, it was not a big concern. That was all about to change on a small island in the Susquehanna River.

2.2 Impact of Three Mile Island

Three Mile Island (TMI) was the only commercial NPP accident of significance to occur on American soil. This accident demonstrated that NPP operators did not understand many basic principles of physics related to the design and operation of their reactors. Even though the plant safety systems responded properly to the accident, it was discovered that there were some systems that were not properly designed to operate in the actual environmental conditions experienced. In the subsequent years, commercial NPP operators improved plant designs, put systems in place to improve safety, and developed training programs so that operators could demonstrate competence in safe operation.

While the drive to improve safe operation continued as a result of post-TMI improvements, it turns out that plant performance also increased dramatically, largely due to increased plant availability. New safety and performance initiatives were put in place to meet additional regulatory requirements with a corresponding increase in plant staffing, but due to increased availability and high electricity prices, profits from nuclear operation continued to grow.

2.3 Impact of Fracking and Renewable Energy Policy on Energy Prices

The energy landscape has changed dramatically over the last 15 years. The development of enhanced energy recovery (i.e., fracking) has opened huge reserves of oil and natural gas at historically low prices, while government subsidies to encourage the development of renewable energy, combined with falling capital costs, have resulted in a proliferation of wind and solar generation. These factors among others have driven the price of electricity down to the point where generation from some NPPs is no longer economically competitive. In fact, it is estimated presently that a significant portion of the U.S. nuclear fleet is economically challenged. Additionally, most NPPs have not significantly modernized large portions of their operations, and are currently utilizing the same analog safety systems that were installed when they started up. Therefore, when market pressures hit, many nuclear generators have found themselves unable to improve efficiency and modernize enough to stay in business. Several nuclear reactors in the U.S. have been shuttered in the last 10 years due to market conditions alone, and more will likely follow unless drastic measures are taken to improve economic efficiency.

2.4 Current State of Digital Upgrades

Most U.S. NPPs in operation today were licensed using state-of-the-art analog technology of the 1970s. While these systems are well proven and designed with multiple redundant channels, they require extensive manual surveillance and testing procedures to demonstrate their continued functioning. In addition, the lack of automated information on component performance requires manual equipment data collection and entry into manual logs and files, as well as time-based preventative maintenance scheduling. All of this adds up to increasing labor costs as the only means to maintain or increase plant availability.

When industrial digital control systems became widely available in the 1980s and 1990s, most plants replaced selected secondary systems with stand-alone digital controls (e.g., Feedwater control). As digital systems have become more mature and have been applied to industrial systems in other industries, many nuclear stations have upgraded most if not all of their secondary systems to the latest digital controls. The resulting performance improvement, along with an increase in plant safety, has been dramatic. However, very few utilities have adopted digital controls for the safety-significant portion of the plant. This is in part due to onerous and complex digital licensing requirements. In addition, the few safety-significant systems that have been replaced were plagued with delays, budget overruns, and licensing risks. These projects created, at the time, a high-risk environment for the rest of the industry resulting in safety-significant digital upgrades not even being considered by virtually all utilities.

Recently, the industry has been working with the U.S. Nuclear Regulatory Commission (NRC) to clarify regulatory requirements for digital upgrades and to streamline the process for NRC approval of licensing changes. There is evidence that these recent changes may improve the regulatory process and reduce the risk so that utilities may consider replacing obsolete analog safety systems with modern digital systems. The benefits provided by these digital systems are numerous—obsolescence issues can be eliminated, plant operations are simplified, and surveillance tests are drastically reduced. In addition, plant safety is increased.

However, many utilities have replaced analog technologies with digital technologies in a like-for-like manner, without exploiting the reduced O&M cost benefits inherent in digital technologies. Many times, the replacements have been piecemeal, driven as a last resort by obsolescence and reliability problems. Other industry sectors have used technology to redefine their operating model into one that is more cost-effective and sustainable. This is why a full nuclear plant transformation approach is needed, whereby a seamless digital environment (Thomas & Scarola, 2018) that fundamentally transforms the NPP operating model is installed, instead of simple, like-for-like upgrades of analog systems to digital.

The U.S. nuclear industry is poised to proceed down one of two paths: either transform itself through digital modernization to improve safety and reduce costs, or continue down the non-competitive path of just maintaining the existing infrastructure. This report will seek to outline a pathway toward total plant transformation (TPT), improving plant safety while reducing production costs.

3. TOTAL PLANT TRANSFORMATION PROGRAM PLAN

3.1 Vision and Goals

In order to accomplish TPT across the nuclear industry, the reasons why the present situation exists must be understood and addressed. An understanding of the current state reveals that significant amounts of time and money will likely be spent, and a significant amount of unproductive organizational churn will occur. The churn will likely be transitory, resulting in the organization returning to the original state at a later date, and failing to reach the transformation objectives. Incremental changes that do not really address the fundamental issues are often implemented, without addressing the factors that are driving cost and efficiency shortfalls.

The U.S. nuclear industry has made transformative changes in plant performance and safety since TMI, and particularly since the early 1990s, as demonstrated by exceptional safety and availability ratings that are the best in the world. The industry must now work to improve the O&M cost structure without sacrificing what has been gained in safety and performance. The good news is that by properly structuring work processes, using digital technology to monitor and control all plant systems, transforming maintenance and testing processes, and eliminating unnecessary regulatory burdens, NPPs can be operated and maintained much more economically while simultaneously improving safety. Figure 1 shows a process whereby current work functions are identified and then categorized such that they can be transformed via a change management process into new work function efforts. The goal of this process is to achieve dramatic efficiencies when transforming each work function.

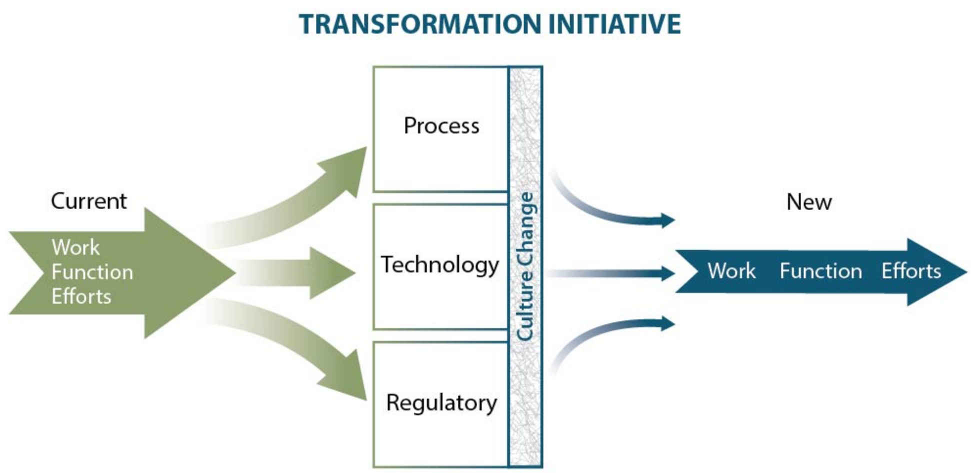

Figure 1. Work process transformation reducing overall effort.

This report seeks to lay out a process that can be applied to every plant in any situation: operating in a regulated or unregulated market; single or multiple units; boiling water reactor (BWR) or pressurized water reactor (PWR); union or non-union labor force. Having said that, while this report is intended to guide each NPP owner with the tools to evaluate their current condition and chart an aggressive path toward competitiveness, each owner must set their own O&M goals for cost and efficiency performance. It is critical that the goals established be clear, understandable, and measurable. It is also of utmost importance that the vision includes the entire operation and each department, including corporate support and all business services. Without a full view of everything required to operate and maintain the plant, it will be impossible to create a transformative vision that will be successful. It is very easy to assume a support function will be available at a fixed cost, or to demonstrate a cost savings due to moving responsibilities to an outside the plant organization without including that support organization in the analysis.

Appendix A, Transformation Process Flow Diagram, is a graphical representation of the various steps required to complete the TPT process review. It provides an example of a step-by-step approach to use this guide. However, this is an iterative process that allows the user to enter the process at any step. The important thing is that work functions are evaluated and compared against regulatory requirements and historic limitations are challenged in order to achieve dramatic reductions in O&M costs.

3.2 Scope

This report provides guidance for evaluating a path toward TPT. For projects that involve small step changes, other guidance documents may be more helpful. To be effective, all plant systems, plant and corporate organizations, and support systems must be evaluated together. Some utilities have highly developed technology modernization programs that seek to solve O&M cost issues using advanced technology while ignoring vital organizational process changes. This will lead to automating inefficient processes, resulting in less than optimum cost savings for the plant. In addition, it may be possible to cut down on equipment and system modifications if the process or system is simply not needed anymore or can be reclassified to a lower safety significance category.

Other utilities have focused their attention on process and organizational changes alone to drive their costs down. While necessary, seeking to optimize a process without incorporating advanced digital systems, tools, and controls will fall short of delivering the desired result due to the limitation of current analog systems and manual processes. In addition, equipment obsolescence and the lack of employees with skills and experience in analog systems will result in increasing costs as time goes on. Optimizing the organizational structure and engaging in process improvement is a vital beginning step toward TPT. Each utility and plant should consider implementing the known process improvement techniques or methodologies. One relevant approach is to use the Nuclear Energy Institute (NEI) Delivering the Nuclear Promise© (DNP) Efficiency Bulletins, or an equivalent process optimization structure. Implementing these change management processes can provide a good basis for starting TPT.

Another area that will be evaluated in this report is the way maintenance and support services are provided at the plant. For most utilities, maintenance, engineering support, chemistry, radiological protection, projects and programs are all performed by in-house staff, sometimes supplemented with contractor support. By comparison, however, many outage functions have been turned over to outside organizations using a performance-based contract structure (i.e., if the contractor delivers, they get a bigger share of the benefits; if goals and expectations are not met, then the contractor does not earn as much). Part of TPT is evaluating the current structure for delivering routine maintenance and support services to determine if there might be a better and more cost-effective approach, such as an approach similar to how most utilities run their outage support services.

3.3 Developing the Transformation Plan

A key aspect in a successful TPT initiative is to develop a plan that can guide the process and keep all stakeholders and processes on track. The plan does not have to be long or complex, but must contain enough information to outline the vision, provide the necessary steps that must be taken, and outline a high-level schedule to follow. Table 1 provides an outline for what a typical review plan must contain at a minimum.

Table 1. Transformation plan contents.

Section	Description
Vision	The vision must contain the reason that the effort is being undertaken. It should describe an end state that is demonstrably better than the current state. It must present the urgency for change (i.e., a compelling reason to move in a new direction).
Goals	Clearly articulate the objective criteria that represents the end state. The criteria must be specific, $/Mwhr, staffing level, etc.
Scope	Outlines the boundaries for the change process, what is included and not included.
Process	Describes how the process will be conducted and who will conduct the reviews.
Schedule	Outlines when changes are expected and also includes schedule for short term wins.
Implementation Team	Describes who will be leading the initiative by name and position, if possible. If a consultant is involved, they should be named as well.
Communication	This area is often overlooked, but is critical. It will describe how the effort will be communicated to employees and how they will be involved in review and feedback.

The Transformation Plan must be developed at least in part by stakeholders that will also serve on the TPT Review Team (hereafter just called the Review Team). Having a consultant develop the plan and then expecting company stakeholders to accept and embrace the plan is a serious mistake. Of course, having a consultant with relevant credentials participate and provide input on the plan can greatly enhance the plan and give it more credibility. Expert assistance may also be found in national research laboratories, research institutions, and industry trade associations such as DOE, Electric Power Research Institute (EPRI), and NEI, but internal buy-in is, nevertheless, essential to the success of a TPT effort.

3.4 Assembling the Review Team

There is no more important aspect of a successful TPT than assembling a strong and influential review team. The team should consist of six to twelve full time staff members who are dedicated to the transformation vision and have the experience and management power to influence others. They must be able to work within and outside of the normal management processes to drive change and coordinate all program activities toward a central end state vision. They must also be able to coordinate with and influence part-time change agents spread throughout the plant and organization. One overlooked aspect of the transformation team is the need for courage. Change is hard, and utility culture is steeped in the belief that "we have always done it this way." It is critical that management appoint people that are not only technically qualified, but also possess a forward-thinking attitude to see the project through to completion. Table 2 represents the makeup and qualifications for a typical review team.

Table 2. Review Team makeup.

Team Member	Function
Executive Sponsor	Sets the vision for the team and drives change for the organization. Must be directly involved, not just a figurehead.
Team Leader	Must have plant qualifications and diverse experience in multiple departments in the plant for credibility. Senior Reactor Operator (SRO) or equivalent training and experience preferred.
Corporate Representative	High level business leader with contacts and power to influence the corporate organization, serves as liaison to corporate executives and boards.
Maintenance	Must have served in a high-level maintenance position (e.g., maintenance director or maintenance discipline manager) and have the respect of the maintenance organization.
Operations	SRO and preferably Shift Manager, outage support experience also preferred.
Engineering	Respected engineering manager at the plant, Professional Engineer, projects and programs experience desired.
Licensing	Experienced licensing manager desired. May be a consultant with equivalent experience.
EP and Security	High level manager with broad experience. Knowledge and contacts with local emergency response and law enforcement desired.
Outage	Outage manager or equivalent. Contacts with outage support organizations are essential.
Support	Team member with skills and experience in materials control, document control, assurance, or equivalent.
Communications	May be part time, but it is critical that they be involved in the project from the start. Must be high enough level in the organization to have the respect and trust of upper management.
Transformational Change Consultant	Consultant with demonstrated results in helping other industries navigate change. May also be from other research organizations (DOE, EPRI, etc.).

3.5 Communication

For TPT to be successful, it must result in a culture change for utility employees. Culture change often takes a considerable amount of time, and in a stepwise fashion. Effective communication is a tool that must be used to inspire change, encourage employees to participate, and report on actual progress. It is important that the executive sponsor communicate the vision early and often and that he or she also "walks the talk."

The vision statement must be developed early in the project and communicated to employees in many different methods and media. In addition to traditional media, like posters or employee newsletters, the vision and progress of TPT should be described and reported via social media, video interviews, and live events. It is important to have a mechanism for employees to provide feedback into the process and to show that their comments and ideas can have a meaningful impact on the effort. A mistake to avoid is to give the impression that the company leadership has hired a consultant who is developing a plan behind closed doors that will be rolled out at some future date. Equally important is to report accurately on failures and setbacks in the project; nothing will inspire trust in a management initiative more than being open when things do not go as planned.

4. DEVELOP AND END STATE MODEL OF THE ORGANIZATION

4.1 Getting Specific with the Vision

In order to achieve actionable results for TPT, the vision must be translated into specific and measurable goals that can then be used to derive action steps. Vague statements such as “we need to be competitive” or “we must reduce our costs drastically” rarely do more than frustrate the organization and can actually harm progress toward lasting and sustained transformation. At this point in the nuclear industry’s history, everyone is seeking to reduce costs, and most employees are wary of the next downsizing, rightsizing, or consolidation initiative, having lived through many of them in the last few years. However, true transformation where non-value-added work is eliminated, low value regulation is revised, and new tools and technology are supplied will energize employees and motivate them to want to participate in this cultural shift.

In order to establish a meaningful and lasting vision, it must be described in objectives terms and goals that are simple, easily understood, and measurable. In addition to the objective goals that reflect certain business objectives, the vision should describe what the organization looks like, how it functions, how it is governed, and how it conforms to certain principles in organizational design. Table 3 describes some of the objectives that may be utilized to describe the vision.

Table 3. Example transformation goals.

Objective	Description
Achieve busbar costs of $X/Mwhr by 20XX	Specific and measurable Global goal
Reduce O&M costs by $X.X by 20XX	Specific to plant or organization
Achieve total staffing level of X at plant Y	Specific to plant
Reduce capital expenses to $X by 20XX	Specific to plant or organization
Achieve a(n) X% cost reduction in O&M and capital costs by 20XX	Must set a baseline for beginning evaluation period
Outsource X% of plant programs to external vendors	Must be specific and measurable and compare actual costs and risks
X% of direct staff are generalists while specialty expertise is outsourced	Specific to plant
Support functions are consolidated at the fleet level	Based on fleet and company goals and resources

In most cases, the objectives established will include a variety of factors that will drive profitability for the company. However, once the objectives are set, it is important to stick with them so that the Review Team has a goal to shoot for, and employees believe that management is serious about transformation. Of course, sometimes business realities change, and the goals must be adjusted. When this happens, it is important to communicate clearly with the employees and explain what caused the change. Pretending that it did not change or not addressing the change is a sure way to discourage the employees and builds lack of trust in the team.

Once the overall vision is set in specific and measurable terms, the Review Team can begin developing the specific features of what the future state will look like in the organization. The two ways to evaluate the future state of the organization are to use the TD approach or the BU approach, but in actuality, both the TD and BU function reviews should be evaluated to obtain a full picture of the level of transformation that will be required to achieve the end-state vision.

4.2 Top Down Work Function Review

In the TD work function review, the end state is represented by staffing numbers and costs that total up to the future state vision. These are represented by full time equivalents (FTEs) on an organizational chart, along with O&M non-labor costs for each section that add up to no more than the future-state costs. This is an iterative process as each organization and work unit is assigned a labor quantity and costs based on the knowledge of the review team. In addition, regulatory requirements for minimum staffing and legal obligations for external payments must be kept in mind. Ideally, this is a starting point that is later confirmed or adjusted by the BU analysis. It is not important that these numbers be precise at this point, but rather be simply a reasonable allocation of the available resource across the entire future organization. These numbers then provide a target for the amount of labor and cost reduction that is sought in the TD work function analysis for each organization.

In order to keep track of all work functions, activities, and the data associated with each, it will be necessary to develop a manual tracking system or create a database that contains the necessary fields. The DOE LWRS Program has developed the Work Function Analysis Tool (WFAT) that can be used to capture data for the as-is state, along with data on the future state vision. The WFAT can also capture the transformational ideas that will be utilized to change the process and ultimately reduce costs. Reports can be produced to evaluate the gaps between present and future state and allow a near real-time assessment of how the team is progressing.

If the WFAT is utilized, the final state numbers should be entered in each work organizational section analyzed. Once all data are entered into each of the work sections, then the roll-up summary should match the end-state vision.

4.3 Bottom Up Work Function Review

The BU work function review is the exact opposite, but parallel process implemented by the TD review. In the BU process, the as-is state is taken as the baseline, and transformational initiatives are identified and evaluated to determine if enough savings can be harvested to reach the end state vision. Sometimes BU reviews can result in evolutionary ideas, but miss a major transformational concept that is more apparent from the TD review. However, the value of the BU review is that it will capture the regulatory requirements that must be addressed, along with interactions with other departments or unknown institutional time expenditures, such as emergency plan duty or training requirements.

Typically, the TD process has labor and budget allocations down to the organization level, while the BU process analyzes work functions that do not have budget allocations. Then, in the ideal case, the work functions are assigned to organizations, such that the BU aggregate labor and budget requirements of the work functions (with all transformational initiatives credited to lower resource requirements) are compared to the TD labor and budget allocation to ensure that they do not exceed these figures. If they do, the result is a gap that must be closed by either the application of additional transformational initiatives (e.g., BU) or additional labor and budget allocation (e.g., TD). If additional labor and budget allocations are made to a particular organization, then the allocations to other organizations must be reduced to compensate for this. Otherwise, the end-state vision objective criteria might not be achieved.

When meeting with stakeholders from throughout the organization, they will typically come from the BU perspective and suggest ideas that makes the present state better. These ideas should be captured and catalogued for consideration later on since many of the most effective cost savings ideas come from a BU idea applied to a TD organizational structure. In other words, the cost gap closure may come from the combination of a BU idea and TD idea working in tandem. Figure 2 shows the relationship between the TD and BU evaluation process.

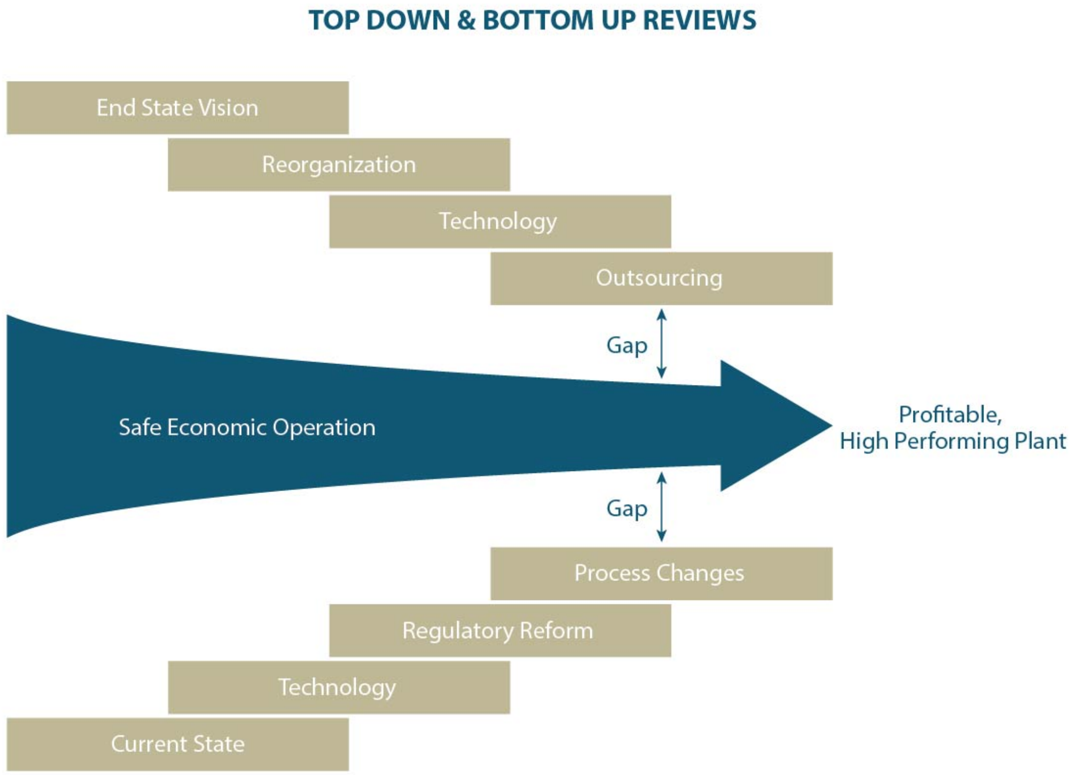

Figure 2. Relationship between top down and bottom up reviews.

At this point in the process, it is not clear how or if there are enough realistic transformation initiatives to yield the cost savings necessary to achieve the end state vision. However, since this is an iterative process, it will become clearer as the process is initiated and each transformation idea is further developed with realistic assumptions.

5. WORK FUNCTION ANALYSIS

5.1 Data Collection

In order to achieve TPT, accurate and complete data must be obtained regarding the costs and work function allocations for the current plant state and the desired end state. One benefit of performing a plantwide (including corporate support) analysis is that all costs and impacts must be considered together so there is no possibility of hiding supposed process improvement savings by moving the work and responsibility to another department or group.

The first step in work function analysis is job and task mapping, and a critical aspect of this step is deciding at what level the data are to be collected and analyzed. If the level is too low, the amount of work required to collect the relevant information will be so great that the analysis will bog down because there is too much detail to get a good view of the overall job function. If, however, the level is too high, useful information about job functions and how process improvements, technology and regulatory changes impact the job function will be lost.

Work functions should be stated at the highest level where general products and outcomes are the same, labor resources (education, skills and qualifications) are generally equivalent, and support resources (equipment, facilities, etc.) are generally equivalent. This will prevent defining an unwieldy number of work functions that have to be analyzed. For example, a sensible work function could be chemistry sampling and analysis. This would cover a broad range of specific sampling activities. It would be too detailed to name specific sampling activities as work functions as this could increase the number by 1–2 orders of magnitude.

It is important that the as-is and the future state results of the data analysis be considered in this step. If the as-is state is based on current organizational structures (i.e., the current organization chart) instead of work functions, it may be difficult to map the future state from the present state. If, however, work functions are described and evaluated, it will be more meaningful since these are unlikely to change unless a transformational initiative eliminates the function. Therefore, every effort should be made to begin the process at the work function level. Table 4 contains some ideas to consider when selecting the appropriate level of analysis and determining a reasonable Work Breakdown Level (WBL) to use.

Table 4. Work Breakdown Level considerations.

Step	Description
Identify primary WBL (e.g., Operate, Maintain, Support, etc.)	Decide on how specific your top level roll up should be. It should be no more than three to five primary functions
Determine lowest level of data to be collected	FTE or percentage thereof (e.g., any activity greater than 100 hr. per year, 10 hr. per month, etc.)
Determine how to handle support functions	Identify support functions at a department level if possible, and then total for a view of impact
Identify any contracted or outsourced support currently used	Break down support costs by work function if possible

5.2 As-is Data Development

For development of as-is data, it is important to identify sources of information that can provide details about level of effort and funds spent on work functions. Budget packages and organizational charts are a good place to start, but work function representative interviews may be required in order to determine how much time is actually being spent on a task or activity. For many NPPs and utilities, implementation of NEI's DNP initiatives has resulted in significant reorganization and task mapping in order to implement the process changes. This information, along with other recent process reorganization data, can be very useful in completing the task mapping.

When conducting the work function representative interviews, it is important to brief the participants on the goals and objectives of TPT in order to make them part of the process. In addition, many improvement ideas will be generated by employees who operate and maintain the plant.

5.3 Future State Data Development

The development of future state data has been described previously in Section 4.2, "Top Down Work Function Review." Even though it may be difficult, it is important that TD data be identified and recorded to the same level of detail as described in section 5.2, "As-is Data Development." As the analysis proceeds, it will become clearer which transformation initiatives have the potential to improve efficiency and reduce costs to the degree necessary to achieve the end state vision. It is important to realize that the initial ideas about how the new organization should look may change as new ideas, organizational structures and technologies are evaluated. Therefore, the pathway to the future state may change, but the vision and goals will remain the same.

It is important that work functions are assigned to future organizations and the aggregate labor and budget resource requirements of the assigned work functions are compared to the TD labor and budget allocations. Gaps are identified as either a positive or negative residual.

5.4 Use of the Work Function Analysis Tool

The WFAT is a relational database that is custom built to capture the as-is and future state and help analyze various transformation initiatives that can close the gap between a plant's present and end state costs. The analysis of the cost difference is expected to ultimately result in increased profitability. It is expected that a WFAT program document will be published and will describe the use of the WFAT along with the definition of input fields and output reports that are available. It is not necessary to use the WFAT to perform a TPT evaluation, but it will make the job easier since it has been built with this particular use in mind.

6. REGULATORY ASSESSMENT

6.1 What is Really Required?

Nuclear power has made great strides in achieving higher levels of safety margins and plant reliability in the last 30 years, due at least in part to strong regulatory oversight. Even though the law regulating nuclear power is relatively brief, and the relevant Code of Federal Regulations (CFR) citations for operating, maintenance, training, and certification activities would fill only a few small volumes, the plethora of codes, standards, Regulatory Guides, NUREGs, and generic issue notices would fill a small library. In addition, each plant maintains at least a full shelf of individual licensing documents to describe and guide almost every aspect of plant operation. However, many of these licensing documents were created to address specific issues, or were designed to address a weakness in plant performance in the days when NPPs were challenged to avoid transients and had low safety and availability ratings.

In the last 20 years, NPPs have operated more reliably and had better efficiency ratings than at any time in history. Plant modifications have eliminated most single point vulnerabilities, and other stand-alone, but nonetheless modern, digital enhancements on secondary systems have virtually eliminated plant trips and resulted in an overall plant industry availability factor of over 92%. In addition, the modifications made in response to Fukushima, including FLEX equipment, have increased the margins of safety for plants significantly.

After TMI, the industry formed its own watchdog organization, the Institute of Nuclear Power Operations (INPO), to drive safety improvements and provide metrics by which all domestic plants could evaluate their performance. INPO has done its job and has provided a valuable service to the industry by participating in the drastic performance improvements the industry has seen. Now, however, many plants are near the maximum achievable safety and performance standards, so any additional improvement in these areas may be unnecessary and prohibitively expensive, without providing a corresponding safety benefit. It may be that monitoring plant performance can be done using forward looking advanced analysis tools and big-data analytics instead of relying on backward looking performance indicators.

Other organizations have also unintentionally contributed to this margin creep. Standards organizations, trade organizations, and industry working groups have developed guidelines and standards that, due to a previously exclusive safety focus, may have required more activities or functions than required by NRC regulations. By clarifying the foundational principles and requirements, more efficient ways may be identified to achieve the same safety benefit(s).

If nuclear energy is going to continue to provide a safe and reliable source of electricity to this nation, transformation must extend to regulatory and oversight bodies as well. Trying to transform the industry one plant at a time may not be possible, and will certainly be hindered if the regulatory oversight function is not transformed at the same time. This is not to say safety will be decreased in any way—on the contrary, application of advanced technologies and data analytics will help drive increased safety and operational performance.

6.2 Regulatory Margin Creep

Traditionally, to meet a safety requirement, plants added margin around the safety requirement to address any unknowns and avoid coming too close to a regulatory limit. For that same safety requirement, implementation of INPO standards may have added additional margin on top of the already generous margin. In order to avoid coming too close to an INPO standard, the plants may have added additional margin for their own peace of mind. These cascading margin additions were usually done by lower level staff without evaluating the overall effect of these changes. Over time, the regulatory limit imposed on the plant bore very little resemblance to the original NRC safety requirement. While it is understandable how this could happen, untangling these cascading requirements will be challenging.

While it appears that adding unnecessary margin on top of a regulatory requirement improves safety, this may not be the case. When actual regulatory requirements are obscured by this behavior, it becomes nearly impossible to determine where to focus limited plant resources. When it is not clear what the true margin is, resources may be utilized in areas of less safety significance instead of issues of greater safety significance.

As part of TPT, each reported regulatory requirement should be evaluated to determine whether there has been unnecessary margin added, or the requirement has been interpreted correctly. In addition, it may be possible to utilize risk-informed improvement programs such as 10 CFR 50.69 to re-evaluate the component or system function, and its attendant operations, maintenance, and supply chain for adjustment. Each regulatory requirement that is identified as a work function in the review must be evaluated on the basis of risk and safety impact. Figure 3 shows how each requirement should be passed through the “lens” of a risk evaluation to determine what is really important and the nature of the true commitment.

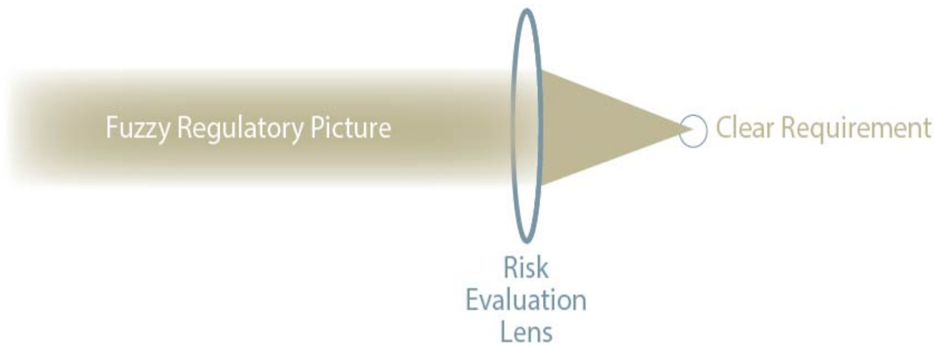

Figure 3. Clarifying regulations through risk evaluation focus.

6.3 Eliminating Low-Risk Activities

In order to implement TPT, eliminating unnecessary regulatory burden is important to improving plant performance and efficiency. Each requirement should be reviewed and understood to determine the impact it has on meeting the plant’s licensing and design basis. Of course, it is understood that this is a very involved and complex process, so the Review Team should focus on only the highest-priority issues or those most likely to provide the greatest benefit during the initial review. Licensing basis and design basis documents must be maintained up to date, but the addition of new technology and/or process changes may allow the revision of these documents for improved efficiency. The licensee is required to provide a reasonable assurance of safety in all plant activities. However, the regulator and plant staff have sometimes been driven to seek absolute assurance of safety, which is not possible, practicable, nor required.

As has been mentioned before, regulatory transformation is underway at the NRC. For example, the 10 CFR 50.69 process allow systems and equipment to be reclassified as having low safety significance, thereby opening up opportunities for efficiency improvements and cost savings without reducing safety. In addition, probabilistic risk assessment (PRA) methods can also be used to evaluate plant risk and help determine activities and processes that can be adjusted. In addition to PRA insights, risk evaluations can be conducted based on expert opinion and operating experience. Not every change to the plant or its processes needs to have a PRA analysis before a decision is made; however, the consideration of risk insights can help prioritize and justify decisions based on their safety significance and available margins.

The NRC has recently issued several documents that will provide improved regulatory certainty for digital upgrades. Regulatory Issue Summary (RIS) 2002-22, Supplement 1, provides a risk-based process for evaluating digital upgrades to many low safety significant safety-related systems under 10 CFR 50.59.

In addition, NRC has issued Digital Instrumentation and Control Interim Staff Guidance (i.e., DI&C ISG-06), that will allow a more efficient process for preparing a Licensing Amendment Request for safety related digital I&C modifications.

One additional important area that should be investigated for modification is the cybersecurity program. Cybersecurity is a critical program, but many in the industry have concluded that the current NRC regulation is a one size fits all program that does not distinguish between safety-related and non-safety-equipment. It was also developed without the aid of risk insights; instead, it takes a deterministic path that does not distinguish between critical components and components with little or no impact on plant safety.

After evaluating NRC requirements, the TPT team must investigate other regulatory drivers that may be affecting the efficiency of the plant without a corresponding improvement in safety. Table 5 identifies the categories of commitments that should be investigated in this process.

Table 5. Regulatory commitments to be evaluated.

Document	Potential for Change
Plant design basis/licensing basis documents	The addition of new digital technology may allow for the elimination of some surveillance testing, revision of commitments, etc.
Reg Guides, industry standards, NUREGs, etc.	Since many of these documents demonstrate an acceptable way to meet regulatory requirements, they may need to be revisited to determine if the most efficient process is currently being utilized.
Industry guidance documents, INPO, NEI, EPRI	These documents are very similar to documents described above and usually describe one acceptable way of meeting requirements. However, some documents and programs live on due to industry inertia and may not be providing a valuable benefit any longer.
Plant procedures, corporate procedures, and plant processes	These documents contain many requirements that are not actually required by regulations, but have been built up over the years to address specific plant issues.
Performance Indicators	These metrics were designed at a time when it was necessary to improve plant performance and cost was not an issue. However, it may be time to reconsider new measures of performance based on digital plant monitoring and forward-looking indicators.

In evaluating changes and revisions to regulatory requirements, it is important to work with other nuclear industry groups that are performing important efforts in the regulatory arena. NEI generally leads and coordinates NRC regulatory reforms undertaken by the industry and should be directly involved in any regulatory or risk initiatives that have broad applicability across the U.S. fleet. EPRI and owners groups also provide an important perspective and may have reform initiatives of their own that should be considered in any transformation program.

7. TECHNOLOGY ASSESSMENT

7.1 Technology Transition

The U.S. nuclear industry is at a crossroads for our existing fleet of Light Water Reactors. Commercial NPPs were designed in the 1960s and 1970s and utilized the latest safety and control systems available at that time. These systems have served the industry well, as demonstrated by the exceptional safety and operational performance of our fleet to date. However, just like a perfectly good house in the 1970s now needs an upgrade to kitchen and bathrooms, our plants must be modernized to incorporate the latest digital technologies to continue to supply reliable and economic power well into the 2060s.

Digital technology is not new and has now been applied to all major industries to drive performance improvements and cost savings. In fact, many industries have turned to digital transformation in order to survive during economic downturns or remain competitive during times of intense competition. As stated by Thomas and Scarola (2018), moving forward, application of digital controls, digital safety systems, and digital plant condition monitoring is the only realistic path forward for a healthy and prospering nuclear industry.

The new nuclear power reactors that are being built presently around the world are using advanced digital controls. In addition, small modular reactors and advanced non-light-water reactors are all using exclusively digital controls for their new designs. Most of our domestic commercial NPPs have applied at least some digital controls in the secondary non-safety system, but they usually exist as islands of digital automation in a sea of analog systems (i.e., are stand-alone).

Digital technology is currently available from nuclear power vendors to completely transform the existing plant systems from analog to digital. There have been a few difficult projects over the last 10 years involved with upgrading safety systems to digital that created a reluctance on the part of plant owners to go digital. The issues primarily involved regulatory uncertainty that led to delays and cost overruns. However, the NRC has recently revised several guidance documents dealing with digital modifications, and is undergoing a regulatory transformation of its own that should encourage investment into safer, more-efficient all digital systems.

7.2 Enabling Technologies

In order to transform our nuclear power stations into the economically viable emission free generators of tomorrow, digital technology must be used throughout the organization and the plant. There are, however, some investments that must be made to allow the digital transformation to take place. Table 6 lists some of the more common enabling technologies that are presently available and should be considered.

Table 6. Enabling technologies.

Technology	Benefit
High bandwidth wireless network throughout the power block	Enables a host of digital technologies, including equipment performance monitoring, mobile work packages, virtual training, outage support, etc.
Smart electronic procedures and work packages	Integrated with plant mode and lineups, these technologies can reduce mistakes, make work performance more efficient, reduce staff to perform the work, and reduce oversight staff.

Technology	Benefit
Mobile field devices	Allow performance of tasks on-line, access to all information to perform the task (e.g., vendor manuals, work instructions, training videos, etc.)
Components instrumented for monitoring	Provides data on component and system parameters for evaluation of maintenance requirements and improvement of plant performance.
Component database, maintenance management, materials management, and business process management system	Provides critical plant information on components and systems and allows applications to utilize and interact with these data (INDUS, SAP, etc.).
Digital information architecture	Seamlessly integrates all of the operational technology and information technology (OT and IT) so that information flows effortlessly from source to any point of use.

It is important to note that implementation of enabling technologies should be considered as a necessary investment into plant modernization, and not an end in itself. Also, the investment required to install these systems may not yield the cost savings necessary to achieve a positive initial return on investment (ROI). They must be viewed as enabling other technologies that will yield greater benefits (e.g., a longer-term ROI) once implemented.

7.3 Transformational Technologies

In order to achieve the objectives of TPT and the attendant cost savings, transition to modern digital technologies must occur relatively soon, occur relatively quickly, and be complete. The longer that the domestic fleet continues to maintain obsolete analog equipment, the harder it will be for the U.S. to achieve the efficiency we need to cover our costs and remain a profitable business. Since the approval of Subsequent License Renewal, plant owners have the planning horizon to upgrade major systems to digital and improve the performance of the plant, while at the same time improving safety.

As has already been mentioned, most plants have upgraded much of their secondary systems with standalone digital controls with a corresponding improvement in trip reduction and the benefit of lower maintenance costs. However, to achieve the efficiency and cost savings goals of TPT, total digital transformation will be required (Thomas & Scarola, 2018). For example, with an all-digital control room, many Tech Spec required surveillance tests can be eliminated. Table 7 describes some of the currently available technologies that should be considered for TPT.

Table 7. Advanced digital technologies.

Technology	Description
Non-safety related digital controls	Automation of secondary functions, including turbine, feedwater, stop valves, and moisture separator reheater controls. New digital systems should be deployed in a distributed, but integrated architecture.

Technology	Description
Digital safety-related systems	Digital reactor protection system (RPS), engineered safety features actuation system, plant protection system, reactor trip system, and core protection computer
Advanced control room alarms	Replaces traditional annunciators with smart alarms and integrated displays
Digital Control Room—glass	Fully digital control room with all digital features and controls, including digital safety systems.
Computerized Operator Support Systems	Provides assessments and recommendations to augment operator decisions.
Digital field component control	Allows direct control of actuated components by software, eliminating the majority of field relays and interlocks.
Smart transmitters and field-input devices	Digital input devices interface directly with digital control and safety systems. Will allow for reduced calibration frequency and improved failed-input management.
Virtual Emergency Operations Facility	With fully digitalized control room, all relevant plant data is available anywhere to anyone with a computer and authorization.
Automated chemistry sampling	Analytical instruments providing chemistry data to the central data base for reporting.
Advanced training tools	Utilizing video instruction, just in time training and other advanced methods instead of standard classroom contact hours holds promise of better and more efficient outcomes.
General automation technologies	Any technology that can automate manual tasks while eliminating human error and maintaining safety.

7.4 Data Analytics

Data monitoring and analytics provides the potential for tremendous cost savings that can be achieved from migrating the current manual and labor-intensive surveillance and preventive maintenance activities to data-driven online monitoring methods. Once components are instrumented thoroughly, and a high bandwidth wireless network is installed in the plant, this real-time information can be used to predict plant performance issues, detect incipient component failures and provide the basis for performing preventive maintenance activities as needed rather than on a schedule.

The DOE LWRS Program recently completed a project that fully describes what is required to implement a plant monitoring program. That report*, Development of a Technology Roadmap for Online Monitoring of Nuclear Power Plants* (Al Rashdan et al., 2018), is available and a good resource for outlining the value and cost of a plant monitoring program.

8. PROCESS CHANGE ASSESSMENT

8.1 Previous Process Change Efforts

Beginning in 2016, NEI began an effort to gain efficiencies in plant processes to improve performance and reduce costs while not impacting safety. Some of these efforts were targeted at working together as an industry to structure support services in such a way as to make them more efficient for everyone. As an example, the industry participated in using one background-information database so that contract employees who were approved to work at one facility could also be approved to work at any other NPP. The most significant of these particular initiatives was agreed to be implemented by every NEI member nuclear plant.

Other improvement efforts focused on how each individual site could improve performance by eliminating low value work or reorganizing a work process or function. Over 63 DNP Efficiency Bulletins were developed by industry teams, and many have been implemented across the industry. NEI reports that implementing these improvements has reduced O&M costs significantly. In order to implement TPT, it is vital that all DNP Efficiency Bulletins be evaluated and implemented to the greatest extent possible.

However, just implementing DNP Efficiency Bulletins alone will not achieve the goals of TPT. DNP focused primarily on process improvements that could be implemented quickly without any regulatory changes and without the addition of plant equipment or technology. When process changes are combined with regulatory transformation and advanced digital equipment, dramatic savings are possible. Figure 4 shows how process change combined with regulatory reform and technology implementation can enable significant and long-lasting reduction in O&M costs.

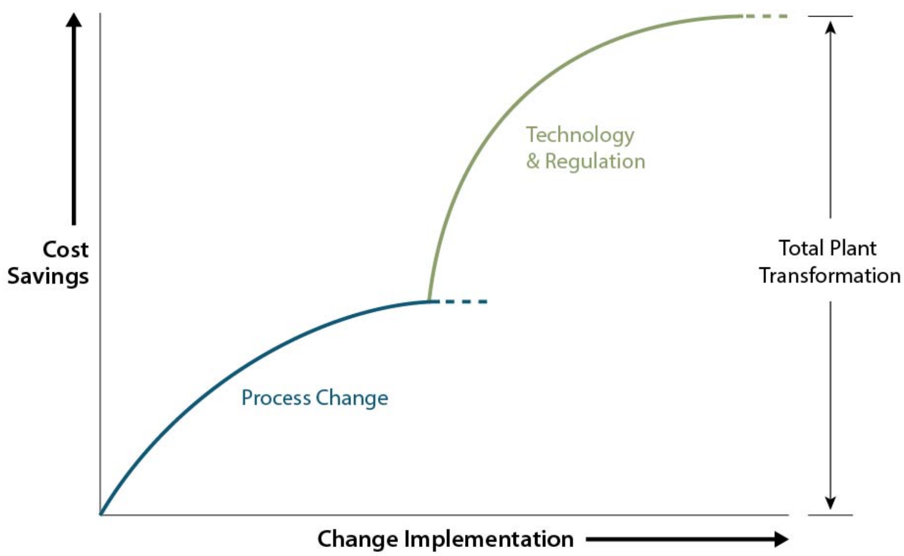

Figure 4. TPT using process, regulatory, and technology change.

As the Review Team evaluates work functions, previous implementation of process improvements should be noted and recorded. In addition, it is often helpful to seek input from plant staff regarding the benefits obtained from these initiatives. In some cases, it has been reported that implementation of some improvement ideas has resulted in an increased workload for the plant staff, rather than a reduction. Repeating this mistake should be avoided, and acknowledgment by the Review Team of these missteps will go a long way toward building trust in the TPT process.

8.2 Process Change Categories

As previously stated, before starting the TPT process, all DNP Efficiency Bulletins should be evaluated for implementation. For those not implemented, a clear reason should be provided for future reference. When combining process change with regulatory change and digital technology, true synergy is obtained. Various categories of process change that can be achieved through this synergy are described in Table 8.

Table 8. Process change categories.

Types of Process Changes	Example(s)	Justification
Stop performing the task	Replacement of analog system with a digital system allows some surveillance activities to be eliminated. Digital storage of records eliminates need to separately copy and store component status information.	If no regulatory or business reason exists for the activity, then it can be terminated. New technology may have made the function unnecessary, or an original misunderstanding of the regulatory requirements resulted in creation of the task.
Revise the work process to make it more efficient	Eliminate unnecessary work steps that do not create value.	Task may be able to be done with fewer resources.
Provide systems or tools to make the process more efficient	Computerized procedures, automated tag generation, and mobile worker platforms make work evolutions more efficient	Use of advanced technology can provide additional information to workers reducing handoffs and delays while meeting all requirements.
Provide the needed service via technology instead of manually	On-line training, self-directed training, digital analysis of samples, etc.	Automation of a service can improve accuracy of the process and reduce human error.
Change the regulatory requirements to eliminate or reduce task	Reclassify equipment to a lower category using processes based on 10 CFR 50.69, to reduce or eliminate treatment activities for testing, maintenance, parts, etc.	Regulatory requirements are met without adding unnecessary additional margin
Outsource the task/activity	Plant programs such as fire protection or equipment qualification may be able to be performed by a specialized vendor.	Can result in better performance for lower cost.
Combine functions previously performed by different craft/groups	Utilize multi-craft workers, multi-discipline engineers.	Qualified employees can perform in more than one discipline for lower level tasks while meeting all requirements.
Consolidate functions offsite	Plant overhead tasks are eliminated from new workers, thereby improving job satisfaction. This may also be combined with outsourcing and fleet support activities.	Efficiency is gained and experience improved by moving functions out of the plant while meeting all regulatory requirements.
Eliminate parasitic tasks by using technology or reorganization	Revise emergency plan to include corporate or other nearby sites. Use automation for fire watch, security, etc.	Evaluate why task is being performed, if new technology is available to perform tasks in a more efficient manner.

Types of Process Changes	Example(s)	Justification
Apply risk-based evaluation processes and automation to reduce quantity of Condition Reports (CR) that must be manually evaluated.	Apply risk ranking to each CR. Utilize automated processes to sort and categorize CRs and identify critical items.	Application of automated risk tools can improve the accuracy of CR ranking while reducing manual processing.

8.3 Industry Culture

For any real and lasting change to occur, a change of culture by the plant workforce is required. Processes can be adjusted, new equipment installed, and regulatory barriers broken down, but without the willing participation of company employees, TPT will almost assuredly fail. In order to succeed with a smaller staff, the remaining people are going be saddled with greater responsibilities for the completion of a wider array of programs and processes. Procedures and plans will have to be simplified, with more reliance on skill of the craftsperson, technician, operator, and engineer. TPT will also likely bring about greater job satisfaction as opportunities to grow and take on new responsibilities will be presented to workers. When routine jobs are eliminated, and new technology is added, the NPP of the future is expected to be a place that will attract new graduates who are comfortable with technology and innovation.

In observing the success stories of digital transformation in the oil and gas industry, they are more than installing advanced digital equipment or clarifying regulatory requirements. They are also about motivating each employee to take full responsibility for making the transformation successful. With this focus on transformation, it is important to remember that all of these changes can and will be implemented while improving safety. Public trust in nuclear energy is based on safe and efficient operation of NPPs. TPT is a way to upgrade for the future, invest in modern technology, provide meaningful jobs for employees, operate efficiently and be a useful and profitable business to support our communities. Figure 5 shows how culture change must be at the center of each transformative initiative to achieve lasting success.

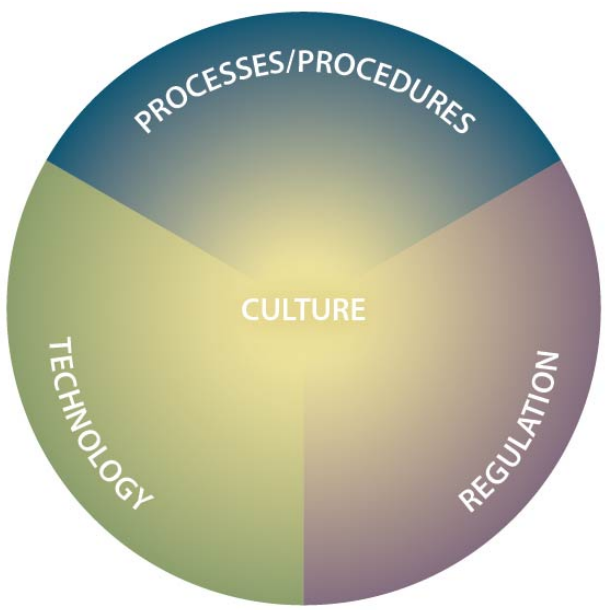

Figure 5. Importance of culture change for implementing TPT.

8.4 Outsourcing

The nuclear industry is very familiar with using prime vendors and AE organizations to perform specific tasks especially for plant outages. Certain specific tasks, such as steam generator inspections or reactor vessel internal inspections, have always been done by contractors due to the specialized equipment and skills required. However, usually contractors are hired for a specific task for a specific time. Some utilities use consultant engineers or project managers as staff augmentation support to their full-time staff. These contractors report to the plant management and do not operate independently of the line organizations.

One idea that should be considered as part of TPT is the idea that experienced companies could be tasked with responsibility for a function in the plant, independent of low-level plant management. As an example, they might be contracted to be responsible for the fire protection program at the plant. This contract might include providing any technical evaluations needed, preparation for NRC or INPO inspections and being responsible for any performance indicators. If the fire protection area was healthy and met all requirements, the contractor might be awarded an additional fee. If, however, an inspection revealed an issue with the fire protection program, the contractor might have to fund the recovery plan and receive a reduced fee for service for that period. In this way, the contractor would have “skin in the game” and would benefit when his performance helped the plant maintain a healthy fire protection program. The plant would benefit by having the program overseen by an industry expert with significant industry experience. In addition, there would be no reason to have a full-time fire protection engineer on site, so staffing could be reduced. This could be a win-win situation if it is structured properly.

9. TASK AND JOB REALLOCATION

9.1 Allocation Strategy

Once existing tasks have been identified and mapped (as described in Section 5), the next step will be to propose a transformation initiative that will close the gap between the as-is state and the future state. Table 9 describes several examples of how this may be accomplished. It is important to remember that when proposing changes, care should be taken to identify any regulatory or economic factors that may be impacted by this change. If the proposed change negatively affects these factors, the Review Team must go back and restructure the proposed change so that these negative consequences are eliminated.

Once all allocations have been determined, they should be totaled to determine if they are able to close the gap between the as-is state and the future state. If gaps remain, the Review Team should go back and explore additional transformation initiatives that will generate the savings required.

Table 9. Example allocation matrix.

Task Description	Position	Proposed Change	Regulatory Impact	Economic Impact	Process Change	Regulatory Change	Technology
Perform surveillance test 6.x for RPS	Reactor Operator	Can test be eliminated?	Technical Specification (TS) change	Can save 0.5 operator FTE		Submit TS change	Digital RPS that performs self-checks and diagnostics
Perform tag-out for maintenance procedure 5.x	Reactor Operator	Reduce time for task		Can save 3 hours	Have tag-outs performed by consolidated operations support center		Utilize advanced tag-out software program
Collect performance data on pumps	System Engineer	Eliminate manual data collection		Reduce system engineering hours by half			Fully instrument components, wireless system in plant, plant monitoring system in place
Prepare fire protection system status reports	Fire Protection Engineer	Outsource task	May have to revise fire protection plan	Reduce costs by 35%	Outsource fire protection system management	Monitor performance of contractor	
Enter chart recorder logs into permanent records	Admin	Eliminate records storage	No regulatory requirement	Reduce administrative staff by 2 FTE	Eliminate task		

9.2 Stakeholder Involvement

It is critical in this effort to keep all stakeholders informed and involved in the progress of transformation. Once an initial review of how all the gaps can be closed using transformational initiatives, this information should be shared with the plant and corporate stakeholders to obtain their input. This would also be a good time to obtain their input on how to move from the present state to the end state envisioned for their area of responsibility. This information should be documented and will be used when developing detailed implementation plans.

Another important consideration is to involve other industry groups that have significant impact on the nuclear industry. NEI should be involved on any issues that involve NRC regulatory interface since they coordinate regulatory initiatives on behalf of most of the industry. NEI also coordinates the DNP program, which has provided important process changes to the way NPPs are operated and maintained. EPRI provides research and application products that seek to improve the performance of NPPs. Many of their products deal with issues, such as plant monitoring and placement of sensors on equipment, that provide a standardized approach to solve complex issues. INPO provides many guidelines and documents that seek to improve plant safety and performance. The PWR- and BWR-owners groups have developed very important plant component and system modifications in the past. An understanding of their goals and projects will aid any TPT effort. Finally, the DOE LWRS Program has produced many groundbreaking studies and reports, and is currently participating in plant and system pilot projects to demonstrate advanced technology and processes to improve safety and economic performance of the nuclear fleet.

10. IMPLEMENTATION PLAN AND SCHEDULE

10.1 Plan Development

Once the analysis has been completed and preliminary management decisions have been made regarding implementing TPT, it is vital that each transformational idea be finalized by the development of an implementation plan. These ideas may be grouped together, but it is important that each idea be developed to the degree necessary for its implementation. Some ideas may be quick and easy to implement while others will require significant resources and may take years to implement. A typical implementation plan will include the elements contained in Table 10.

Table 10. Typical implementation plan elements.

Plan Contents	Description
Detailed description of idea	Describe in enough detail to be clear outside of the Review Team.
Resources required	List any external or internal resources required (e.g., corporate IT).
Schedule for implementation	Level 1 or 2 schedule.
Cost	Include cost to terminate current process, costs to purchase and install new equipment, and O&M costs going forward.
Risks	Identify regulatory, economic, safety, workforce, education, or other risks.
Regulatory impact	Identify fully what will be required to implement any regulatory changes. Coordinate with NEI.
Coordination with other initiatives	Identify and evaluate synergies from implementing with other projects and how to avoid conflicts.
Contingency plans	Describe alternatives to consider when things go wrong, or the technology does not work as advertised.

It may be more beneficial to create smaller transformational plans for specific areas and then have a master transformation plan that rolls these plans together for the most efficient coordination. For example, there may be a plan for technology innovation that includes the details for planned technology upgrades. There may also be a plan just for restructuring job functions and outsourcing activities. Regardless of how it is done, a plan must be developed so that progress can be tracked, and adjustments made as the situation dictates.

10.2 Implementation Considerations

Because implementation of TPT will create disruption for the utility and plant, care should be taken when rolling-out process changes and technology additions. In order to keep plant staff engaged and focused on the end objective, priority should be given to efforts that will result in early wins. If there are smaller changes that can be implemented rapidly, it will encourage employees to participate and believe in the change process, thereby increasing overall chances of success. The nuclear industry is not normally a good model for utilizing the agile method since traditional equipment additions may take many years between conceiving an idea or project and having it actually installed in the plant. However, an effort should be made to deploy systems or process changes more rapidly, even if all the features are not present in the early deployment. Of course, all regulatory requirements must be met before any changes are made, but many times existing cultural biases stand in the way of transformation.

For significant regulatory changes, care should be taken to coordinate with NEI and other stakeholders regarding scheduling of meetings and deadlines with the NRC. An integrated approach to regulatory reform will likely yield better results in a timelier manner than one-off efforts.

11. RISK REVIEW

11.1 Purpose of Review

The overall purpose and objective of the risk review is to identify and evaluate the possible effects resulting from implementation of the revised plant model that incorporates transformational features. This review should evaluate and confirm both the positive and negative effects of the transformation and confirm assumptions made to support these recommendations. In working through and evaluating a large amount of data, it is easy for the Review Team to lose perspective and fail to catch an important element or to be more generous with their assumptions than may be prudent. This review could be broken up into an internal and an external review panel, or the review could be integrated. For this report, it is assumed that a joint review will be conducted by both internal and external reviewers.

11.2 Review Criteria

The review should start at a high level and ask the following questions:

1. Are the goals and objectives discussed in Sections 3 and 4 met?
2. Does the transformation taken as a whole result in the vision described in Section 3?

Once these high-level outcomes are confirmed, then the means of achieving these (all the allocation or transformative initiatives) must be individually evaluated to ensure risk and consequences are managed.

For the review panel, the criteria listed in Table 11 should be evaluated. Issues identified during the review should be resolved, and the transformation plan updated as necessary.

Table 11. Criteria for independent review.

Criteria	Value
Plant safety is maintained at a reasonable assurance of safety level	No transformational changes can degrade the safety of the plant
Regulatory transformation	Have existing unnecessary regulations been challenged enough? Are there examples from other industries that can serve a guide?
Remaining regulatory requirements have been identified, and plans are in place to revise as necessary	Regulatory requirements can be adjusted or revised using the proper review and approval processes
Risks have been identified, and compensatory measures are in place	Reasonable preparation for risks are identified
Economic savings are reasonable and based on sound principles	Validates that the Review Team’s prior estimates of cost savings are accurate
Transformational ideas from other industries considered	Need to go outside of the nuclear industry to gain insights into successful initiatives
Technology utilization	Have all technology options been considered? Are technologies at a maturity level adequate to support implementation schedule?

Criteria	Value
Work process change	Have existing work processes been challenged enough. Is there a better way to accomplish the task?
Culture change	Have cultural implications been considered in the transformation process?
Communication plan	Is a communication plan in place? What has been done so far?
Management and corporate support	What is the level of management support, corporate?

11.3 Review panel makeup

In order to provide a comprehensive assessment of the TPT plan and outcomes, the review panel must consist of individuals that are very familiar with plant systems, regulatory requirements, and plant operation. However, the panel must also contain individuals not connected with the nuclear industry who have experience in transformation from other industries. Table 12 is an example of what the makeup of a review panel might look like. Of course, the Review Team will participate on the panel as presenters and answer questions. It is recommended that the review panel meeting be conducted by an independent meeting coordinator and not a member of the team.

Table 12. Review panel makeup.

Panel Member	Benefit
SRO from another NPP	Perspectives on current regulatory requirements and operational trends
Senior Executive from an outside NPP	Overall business and operational process insight
External research organization	May be from EPRI, DOE or other international organization with relevant experience
Non-nuclear industry representatives	Subject Matter Expert(s) from petro-chemical, aviation, medical or other highly regulated industry that has experience in TPT
Economic business consultant	Consultant specializing in transformational initiatives, economic analysis, process re-engineering, etc.
Technology vendor	For major technology innovations, can provide perspective.
Nuclear power consultant	Independent engineering service provider not connected with any products or services being considered
Human Factors Engineer	Perspective on how the organizational, regulatory and technology initiatives will work together

Once the review has been conducted, the Review Team should consider all input and revise team recommendations as necessary. If new ideas are generated, they should be compared with the current plan, and adjustments should be made according to the value of the idea. A summary of this input meeting should also be prepared and communicated with plant staff.

12. CONCLUSION

The U.S. commercial nuclear power industry is currently working to transform itself to become more cost competitive with other electrical generation sources. Many NPP utility owners and operators are actively working to identify ways to reduce their "all-in" cost to generate electricity. The consensus in the industry, based on multiple analyses, is that the opportunity to reduce "all in" costs is through reducing O&M costs.

The DOE LWRS Program's mission is to work in partnership with the industry to achieve this transformation. This LWRS milestone report describes a transformation process and tools that all NPP utilities can use to evaluate their present state, and set goals for their future reduced O&M costs. The process also guides utilities on how to achieve these improvements. Specifically, the transformation process recommends analyzing current work function efforts and identifying whether the transformation opportunity for each work function is most readily achievable through 1) work process improvements, 2) technology solutions, or 3) regulatory reforms. Additionally, the transformation process recommends that the work functions and three transformation opportunities should be analyzed from both the TD and BU perspectives, and undergo a risk review by an independent review panel. By applying these processes in combination to all current work function efforts, NPPs can achieve the dramatic O&M savings needed to sustain their safe and economic operation into the future.

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14. APPENDIX A – TRANSFORMATION PROCESS FLOW DIAGRAM