INL/EXT-20-59639

Light Water Reactor Sustainability Program

Industry Engagement on Integrated Operations for Nuclear

September 2020

U.S. Department of Energy

Office of Nuclear Energy

INL/EXT-20-59639

Industry Engagement on Integrated Operations for Nuclear

Ken Thomas, Jason Remer
Idaho National Laboratory

September 2020

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy

ABSTRACT

The case for nuclear plant transformation is driven by economic realities combined with new technological capabilities, providing opportunity to transform the business model to a new one that is technically and economically sustainable. Digitization of the current nuclear plant business model will only institutionalize the inefficiencies of the largely manual and paper-based work processes that are now employed. Only through transformation will the full power of new technologies, process changes, and human creativity be unleashed to transform the nuclear utility business into one that is competitive and long lasting.

Through an industry collaboration, the Department of Energy Light Water Reactor Sustainability (LWRS) Program Plant Modernization Pathway is focused on developing a business-driven approach to this transformation, moving from one that is labor-centric to one that is technology-centric, as many other industry sectors have done to survive in the marketplace.

The underlying concept for this operating model transformation is known as integrated operations (IO). IO refers to the integration of people, disciplines, organizations, and work processes supported by information and communication technology to make smarter decisions. Over the past two decades, North Sea oil and gas companies have implemented IO to restructure their operating models to remain profitable amid declining offshore petroleum fields and depressed oil and gas prices. Using advanced digital technologies, they moved operations and support functions onshore to serve multiple platforms as one example of business model transformation. Based on the IO success in the North Sea, the concept of integrated operations for nuclear (ION) was developed as a business-driven approach for transforming the operating.

The purpose of this report is to describe the efforts of the LWRS Program Plant Modernization Pathway to engage the nuclear industry on the transferable learnings of integrated operations for nuclear. It describes the engagement materials developed, the engagement opportunities that have been conducted, and the plans for further industry engagement in the coming year.

CONTENTS

FIGURES

ACRONYMS

ANS	American Nuclear Society
BCMW	Business Case Methodology Workbook
DNP	Delivering the Nuclear Promise
DOE	Department of Energy
EPRI	Electric Power Research Institute
EUCG	Electric Utility Cost Group
I&C	instrumentation & control
IFE	Institute for Energy
INPO	Institute of Nuclear Power Operations
IO	integrated operations
ION	Integrated Operations for Nuclear
LWRS	Light Water Reactor Sustainability
NCA	Nuclear Capability Assessment
NCS	Norwegian Conventional Shelf
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
O&M	operation and maintenance
PTPG	people, technology, process, and governance
R&D	research and development

INDUSTRY ENGAGEMENT ON INTEGRATED OPERATIONS FOR NUCLEAR

1. Introduction

The case for nuclear plant transformation is driven by economic realities combined with new technological capabilities, providing opportunity to transform the business model to a new one that is technically and economically sustainable. Digitization of the current nuclear plant business model will only institutionalize the inefficiencies of the largely manual and paper-based work processes that are now employed. Only through transformation will the full power of new technologies, process changes, and human creativity be unleashed to transform the nuclear utility business into one that is competitive and long lasting.

A number of factors have come together in the past decade or so to challenge the economic viability of the U.S. operating nuclear fleet. In the last few years, the industry has experienced nuclear plant shutdowns for purely economic reasons, and that trend is likely to continue without drastic intervention. The reasons are diverse but boil down primarily to three main drivers: 1) the shale boom that has caused natural gas prices to plummet, 2) subsidized renewables, and 3) declining load growth.

Currently, the nuclear power industry is at a point that, unless major structural changes are made to their operations and maintenance costs, they will likely be priced out of the electricity market and cease operations. This is all the more distressing since, in 2019, the commercial nuclear fleet had their best year ever, with a capacity factor of 93.5% and total generation of 809 billion kWh, an all-time high for both measures.

Through an industry collaboration, the Department of Energy (DOE) Light Water Reactor Sustainability (LWRS) Program Plant Modernization Pathway is focused on developing a business-driven approach to transforming the operating model of a commercial nuclear plant from one that is labor-centric to one that is technology-centric, as many other industry sectors have done to survive in the marketplace.

The underlying concept for this operating model transformation is known as integrated operations (IO). IO refers to the integration of people, disciplines, organizations, and work processes supported by information and communication technology to make smarter decisions. Over the past two decades, North Sea oil and gas companies have implemented IO to restructure their operating models to remain profitable amid declining offshore petroleum fields and depressed oil and gas prices. Using advanced digital technologies, they moved operations and support functions on shore to serve multiple platforms as one example of business model transformation. Based on the IO success in the North Sea, the concept of integrated operations for nuclear (ION) was developed as a business-driven approach for transforming the operating model.

The purpose of this report is to describe the efforts of the LWRS Program Plant Modernization Pathway to engage the nuclear industry on the transferable learnings of ION. It is through this engagement that a transformed operating model based on ION can lead to the cost competitiveness of the operating nuclear fleet and thereby preserve this important component of the U.S. electric supply for the national goals of energy and environmental security.

1.1 Light Water Reactor Sustainability Program

The LWRS program, sponsored by the DOE and coordinated through a variety of mechanisms and interactions with industry, vendors, suppliers, regulatory agencies, and other industry research and development (R&D) organizations, conducts research to develop technologies and other solutions to improve the economics and reliability, sustain nuclear safety, and extend the operation of the nation's fleet of nuclear power plants [1].

The LWRS program has two objectives to maintain the long-term operations of the existing fleet:

1. to provide science- and technology-based solutions to industry to overcome the current labor-intensive business model and associated practices.
2. to manage the aging of systems, structures, and components, so nuclear power plants can continue to operate safely and cost effectively.

The Plant Modernization Pathway of the DOE LWRS program conducts a broad R&D program that addresses the technical and economic sustainability needs of the U.S nuclear operating fleet. It is targeted to ensure that these nuclear plants are positioned for many additional years of operation in support of the national goals of energy and environmental security [2]. The pathway conducts this research in collaboration with nuclear industry partners who share this sustainability objective, including nuclear utilities, industry support groups, suppliers, other research organizations, universities, and consultants/contractors.

Since the inception of the LWRS program, the Plant Modernization Pathway has conducted research activities in a broad range of nuclear plant functional areas, addressing critical issues of technology obsolescence, plant reliability, plant worker efficiency, and operation and maintenance (O&M) cost reduction [2]. The development and demonstration of these technologies and related methodologies have been conducted with collaborating partners, including nuclear utilities, nuclear industry suppliers, and other research organizations. The result is a set of proven technologies that together address the requirements for a much-needed modernization of the legacy plant systems and related operations and support processes in order to ensure long-term sustainability and economic viability. To this end, a research project is being sponsored by the pathway to provide a means of nuclear plant business model transformation.

1.2 Report Organization

This report is organized into the following major sections to provide the background on integrated operations, the development of engagement documents and materials, the summaries of engagements conducted, future planned engagements, and next steps.

Section 1 Introduction	The overall objectives of the project, DOE sponsorship, and report organization.
Section 2 Integrated Operations Concept	The concept of integrated operations, as developed by the North Sea oil and gas industry for their operating model transformation to remain profitable in highly competitive world petroleum markets.
Section 3 Integrated Operations for Nuclear	The adaptation of IO concepts and methodologies for the transformation of the U.S nuclear plant operating model to one that is technically and economically sustainable.
Section 4 ION Industry Engagement	The specific industry engagement activities that have been conducted to date in FY2020 to create awareness and interest in the ION concepts and related developments.
Section 5 Future Engagements	The future engagements that are now committed to or that will be pursued in a more specific engagement of nuclear utilities and their suppliers.
Section 6 Next Steps	The next steps for the ION initiative to further engage the nuclear industry in a transformation of the nuclear plant operating model and industry support structure.

2. Integrated Operations Concept

Integrated operations has been the driving concept for a renewal of the North Sea oil and gas industry. While this concept was developed and deployed by the petroleum operating companies themselves, it was substantially supported by Norway's Institute for Energy Technology (IFE) in developing methodologies and other resources. IFE also has a rich history in research into nuclear operations, automation, and human factors and is a long-term collaborator with the LWRS program. This relationship provides a direct pipeline of applicable knowledge and experience.

Also, based on the success in the North Sea oil and gas industry, integrated operations have been adopted by a number of other industry sectors, including additional offshore oil operations, transportation, communications, and mining companies. It has become something of a discipline in itself, with a large body of research and experience publications from these adopters as well as from research and academic organizations.

> *Integrated operations (IO); refers to the integration of people, disciplines, organizations, and work processes supported by information and communication technology to make smarter decisions. In short, IO is collaboration with focus on production*. [3]

The concept of IO was developed primarily by the international oil and gas industries as a response to decreasing revenues and increasing O&M expenses. They were seeking ways to continue the safe operation of critical and complex offshore oil and gas platforms while minimizing costs. Other industries are utilizing IO, including mining, but we will focus on insights from the oil and gas industries, particularly those involved in drilling and production on the Norwegian Conventional Shelf (NCS).

In autumn 2004, the Norwegian Oil Industry Association decided to implement an industrywide program for IO, being a new self-service concept for remote, real-time management of oil & gas fields on the NCS. [3] The decision was based on the recommendations from a feasibility study indicating that IO could reduce operating costs by 20–30% and accelerate production by 5–10% through the:

- Improvement of decision and work processes through an implementation of IO and transfer of operations to virtual operation centers onshore
- Implementation of IT solutions that support remote, real-time management of drilling operations, reservoirs and production facilities, maintenance, and logistics.

The program's main goals were to establish a common digital infrastructure for Norwegian offshore facilities, industrywide information security requirements for accessing this infrastructure, common standards for the transfer of data from operations offshore to virtual operation centers onshore, best practices for remote, real-time management of oil and gas fields, and a knowledgeable industry that supports IO. The integrated operations concept has its basis in the availability of new technology, particularly increased bandwidth allowing for new work forms and the sharing of data and information across a distance.

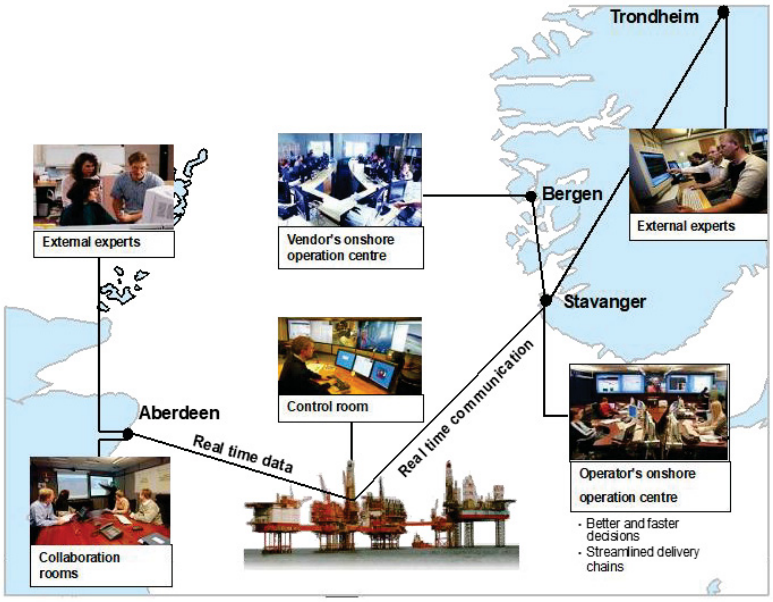


Figure 1. IO concept of remote collaboration.

IO is an approach to solving the challenges of having personnel, suppliers, and systems offshore, onshore, and in different countries. IO is about removing the physical boundaries between people and making cooperation in real time across continents possible. [3] IO involves using real-time data and new technology to remove the divides between disciplines, professional groups, and companies. It is about how the information technology that makes remote operation possible forms the basis for new and more effective ways of working. Real-time transfer of data over long distances can be used to eliminate the physical distance between installations at sea and the support organization onshore, between professional groups, and internally or between the oil companies and suppliers.

When working across professional boundaries and exploiting real-time data and technology that remove divisions, such as time and place, the aim is to ensure a better value creation for the future. [3] Some of the benefits of IO are as follows:

- Improved occupational health and safety
- More efficient operations
- Better reservoir and production control and optimization
- Better monitoring of equipment and more efficient maintenance
- Better resource exploitation
- Increased regularity (uptime).

IO, as developed and implemented by the North Sea oil and gas industry, provided a way to transform their business and achieve competitiveness despite increases in labor costs and dropping revenue. This transformation was performed while still achieving high levels of safety. Given that the operation of offshore drilling and production facilities is very similar in regard to the complexity, safety, and environmental impact to nuclear facilities, IO should be investigated as a model for transforming the nuclear industry.

Traditional approaches to business transformation, which essentially focus on technology innovation alone or on process changes alone, are destined to fail. The strength of the IO transformation model is that

it requires the integration of the transformation process across the four primary dimensions of any business endeavor: people, technology, process, and governance (see Figure 1). [3] In addition, the use of advanced communication and analysis technologies allow most work to be done in the most optimum way independent of physical location.

Figure 2. IO is the integration of people, technology, process, and governance.

3. Integrated Operations for Nuclear

ION is an adaptation of the IO principles and methods that have proven successful in the North Sea oil and gas industry to the nuclear plant operating model to transform it to one that is sustainable in the long term. [4] This effort is being conducted through the following collaborations.

Figure 3. Nuclear plants and offshore petroleum platforms as similar assets for IO application.

3.1.1 Xcel Energy Collaboration

Xcel Energy Inc. is a utility holding company based in Minneapolis, Minnesota, serving more than 3.3 million electric customers and 1.8 million natural gas customers in Minnesota, Michigan, Wisconsin, North Dakota, South Dakota, Colorado, Texas, and New Mexico. It consists of four operating subsidiaries: Northern States Power-Minnesota, Northern States Power-Wisconsin, Public Service Company of Colorado, and Southwestern Public Service Co. [5] In December of 2018, Xcel announced it would deliver 100% clean, carbon-free electricity by 2050, with an 80% carbon reduction by 2035 (from 2005 levels). This makes Xcel Energy the first major U.S. utility to set such a goal. [6]

Xcel Energy is a clear leader in the U.S. nuclear power industry in transforming their nuclear operating model to one that is competitive without subsidies in their regional electric market, which has large components of low-price renewables and gas generation. Using a top-down electricity market price analysis, they have imposed a series of step-down O&M budget reductions on their nuclear organization for each year through 2024 that will ensure this level of competitiveness. Collaborating with the Plant Modernization Pathway, Xcel has adopted the concept of ION as their means of achieving the needed performance improvements and cost savings to operate their nuclear fleet within these future market price constraints.

The Plant Modernization Pathway is conducting research activities with Xcel to apply the principles and methods of integrated operations to their nuclear fleet through significant innovations in how nuclear operational and support activities are conducted. These innovations in turn are being combined into a more efficient nuclear operating model and organizational structure based on advances in digital collaboration and automation. The Institute for Energy Technology is assisting in the project effort to translate applicable lessons from a similar transformation they helped develop in the North Sea oil and gas industry. As a result of these research developments with Xcel, U.S. nuclear operators will have a transferable ION methodology and analysis tool set available for them for use in transforming their own nuclear operating models to ones that are technically and economically sustainable. The central plan is to identify other nuclear utilities that are interested in transformation that would like to partner with the LWRS program to implement ION. In addition to utilities, we will seek to share this transformational program with key vendors, suppliers, and nuclear service providers, since these concepts and practices require the involvement of the entire nuclear enterprise in order to function most effectively.

3.1.2 Institute for Energy Technology Collaboration

Norway's Institute for Energy Technology (IFE), who sponsors the Halden Reactor Project, has been a leader in developing the principles and methods of IO as well as the technologies that enable this transformation. They are collaborating as part of the project team to apply the IO learnings to the nuclear plant operating model.

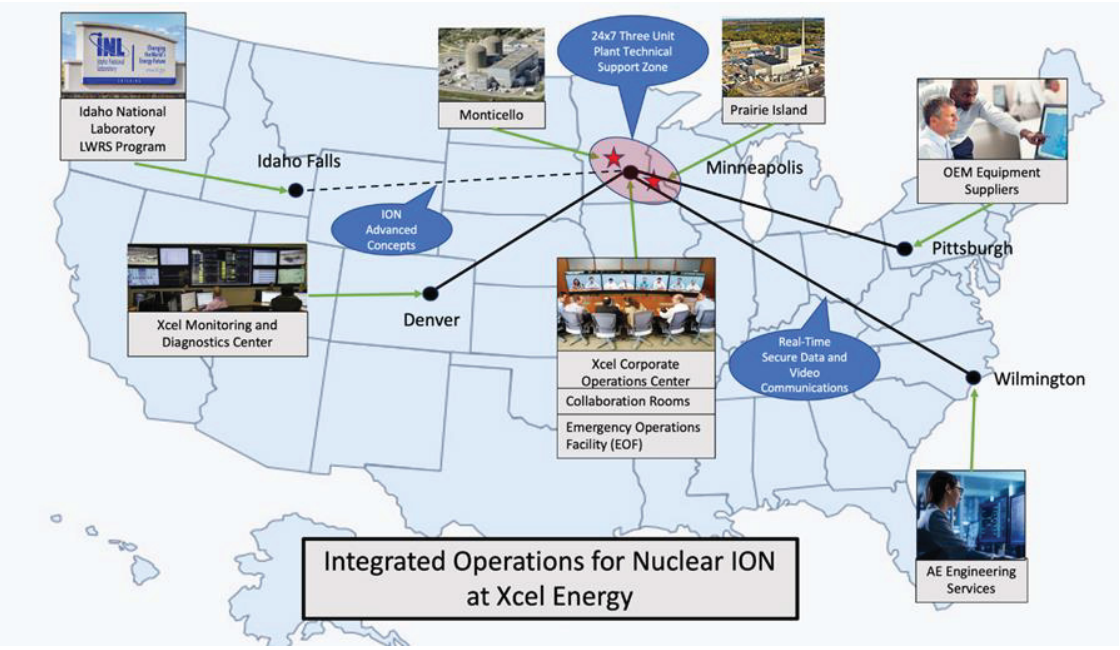


Figure 4. Concept for ION remote collaboration.

IFE has provided a large base of resources related to IO in the petroleum industry. Through the IO Center for Integrated Operations in the petroleum industry, there have been a large number of reports, documents and studies related to IO and its constituent parts. IO concepts have also been used in the mining, airline, and manufacturing industries. However, no studies have been identified that examined using IO principles for the nuclear power industry.

Through support from DOE LWRS, IFE produced a report "Lessons Learned from Integrated Operations in the Petroleum Industry" [3] that provided an analysis regarding the applicability of IO principles gleaned from the petroleum industry to the commercial nuclear industry. Through this report and frequent interactions with IFE, LWRS, in cooperation with Xcel Energy, developed a solid understanding of IO principles and practices.

3.1.3 ScottMadden Collaboration

ScottMadden Inc. is a highly respected management consulting company specializing in energy and corporate & shared services, delivering a broad array of consulting services ranging from strategic planning through implementation across many industries, business units, and functions. [7] They have led major business improvements at the executive level for virtually every U.S. nuclear utility as well as international nuclear utilities.

ScottMadden Inc. is collaborating in this initiative to provide cost benefit analysis and innovative concepts from both the nuclear and other industry sectors. They are also providing innovative concepts in key performance indicators and the effective application of measures to drive desired business performance.

3.1.4 Development of Engagement Materials

Through the collaborations with Xcel Energy, IFE, and ScottMadden, project materials were collected and used to develop project information documents and presentations to describe the ION process and how to implement it. This included figures and tables adapted from IFE materials, with some adapted from other literature, including a book by Andrew S. Grove on organizational transformation, "Only the Paranoid Survive." [8] and an article entitled "Intelligent Energy: A Strategic Inflection Point" [9] written by Marc Lochmann and Ian Platts, which applied the concept of a strategic inflection point to the oil and gas industry. Other materials were newly created to capture specific ION features.

The following specific informational materials are found in these report appendices.

Appendix A	Integrated Operations for Nuclear—Project Summary	This is a two-page summary description of the ION development highlighting the methodology and key activities, including analysis tools.
Appendix B	Integrated Operations for Nuclear—Presentation	This is a standard presentation providing the case for nuclear operating model transformation and key concepts of ION.
Appendix C	Integrated Operations for Nuclear—Project Flyer	This is a one page (front and back) glossy flyer to be used for informational purposes, especially as pick-up material at industry conferences.
Appendix D	Abstract for an American Nuclear Society (ANS) Winter Meeting Paper	This is the abstract for a conference paper that provides a one-page summary of the ION project development.
Appendix E	ANS Utility Working Conference Presentations	Three presentations were made in this Utility Working Conference session dealing with

integrated operations, Xcel Energy IO methodology, and DOE industry engagement.

In addition to this material, a major project report on the ION development was published in August 2020, "Analysis and Planning Framework for Nuclear Plant Transformation," INL/EXT-20-59537. This report is available from the DOE's Office of Scientific and Technical Information website (https://www.osti.gov).

4. ION Industry Engagement

The motivation for sponsoring this research project under the DOE LWRS program is to transfer project results and methodologies to the U.S. nuclear industry to enable operating utilities and suppliers to transform their operating models for technical and economic sustainability. This is being accomplished through the systematic engagement of interested organizations, both in direct communications to organizations as well as through industry meetings and conferences for a more widespread awareness of the opportunities. This section describes those opportunities that have been accomplished to date as well as some scheduled future opportunities. This process will continue in the future to additional organizations and as additional project results become available.

4.1 Major Organizational Engagements

The following are engagements in FY 2020 with large nuclear industry support organizations and large industry meetings where there is a broad opportunity to create awareness among participating organizations.

4.1.1 Institute of Nuclear Power Operations

The Institute of Nuclear Power Operations (INPO) is a major nuclear industry support organization who, along with its international counterpart, the World Association of Nuclear Operators, promotes operational excellence and the highest levels of safety and reliability in the operation of commercial nuclear power plants. It pursues this by establishing performance objectives, criteria, and guidelines for the nuclear power industry, conducting regular detailed evaluations of nuclear power plants, and providing assistance to nuclear power plants to continually improve their performance [10].

On September 25th, 2019, Xcel Energy leaders and INL met with INPO to describe the background and work of the Xcel initiative to transform their nuclear O&M functions as well as to describe the collaboration with DOE/INL on a new operational business model based on integrated operations. This included relating the IO concepts and methods that were successful in the transformation of the North Sea oil and gas industry. The information was well received by INPO in regard to how IO enables much-needed business performance improvements while maintaining standards of excellence.

4.1.2 Nuclear Regulatory Commission

The Nuclear Regulatory Commission (NRC) regulates commercial nuclear power plants and other uses of nuclear materials, such as in nuclear medicine, through the licensing, inspection, and enforcement of its requirements [11]. Plant structures and systems, as well as key operational processes, are subject to NRC regulation, and certain changes pertaining to plant safety must be approved by them.

The ION project was presented to members of the NRC research staff on January 28, 2020, as part of a regular update on the R&D activities of the LWRS program. There was considerable interest in how potential changes in work functions, due to IO operational model transformation, could possibly intersect with regulatory concerns. Overall, the NRC expressed appreciation for the update and asked to be kept informed of future developments for an awareness of possible regulatory matters that would require review.

4.1.3 Electric Power Research Institute

The Electric Power Research Institute (EPRI) is a key partner for the Plant Modernization Pathway, with collaboration made possible through a Memorandum of Understanding adopted in 2010 that links the DOE LWRS program with the EPRI Long Term Operations Program. Since that time, EPRI and the Pathway have collaborated on a number of technology developments as well as jointly sponsoring meetings and other industry collaboration opportunities. The relationship with EPRI is particularly beneficial to the Pathway because of EPRI's research activities, staff expertise, and extensive relationship with utility staff in plant functions that are related to the technology research activities. Periodic phone calls are held with the Pathway leadership and the senior program manager and key staff for the EPRI I&C research.

The team presented an overview of the ION project to the EPRI lead (Rob Austin) for the Plant Modernization Committee on August 4, 2020. This virtual meeting was attended by leaders from the Xcel XE-1 team along with the LWRS ION team. This presentation provided the details of how LWRS is developing the ION program with an emphasis on how the digital technologies will be incorporated into the new business model based on ION.

4.1.4 American Nuclear Society Utility Working Conference

The American Nuclear Society (ANS) is the premier organization for nuclear sciences and technologies for their vital contributions to improving people's lives and preserving the planet. ANS is committed to advancing, fostering, and promoting the development and application of nuclear sciences and technologies to benefit society. [12]

ANS conducted its annual Utility Working Conference on August 20, 2020, as a virtual meeting this year due to COVID-19 travel restrictions. Ken Thomas moderated a panel session exclusively focused on integrated operations. Presenters were Don Bosnic, general manager for Xcel Energy and lead for the XE-1 innovation team; Hank Butterworth, general manager for Xcel; and Ken Thomas from INL. The session was well attended, with over forty attendees. The three presentations are included in Appendix E.

4.1.5 Nuclear Energy Institute

The Nuclear Energy Institute (NEI) is the policy organization of the nuclear technologies industry, based in Washington, D.C. NEI has hundreds of members and, with their involvement, develops policy on key legislative and regulatory issues affecting the industry. NEI was founded in 1994 from the merger of several nuclear energy industry organizations, the oldest of which was created in 1953. NEI's members include companies that own or operate nuclear power plants, reactor designers, and advanced technology companies, architect and engineering firms, fuel suppliers and service companies, consulting services and manufacturing companies, companies involved in nuclear medicine and nuclear industrial applications, radionuclide and radiopharmaceutical companies, universities and research laboratories, law firms, labor unions, and international electric utilities [13].

The project provided an overview of the ION development on August 25, 2020 to key leaders at NEI with a particular emphasis on how the ION concept can be a logical extension of their initiative to reduce the cost of nuclear power known as "Delivering the Nuclear Promise (DNP): Advancing Safety, Reliability and Economic Performance" [14] and incorporating DNP Efficiency Bulletins where complementary to the ION business model. The presentation (Appendix B) was well received by this NEI leadership group with a request to provide more detailed descriptions of the ION concept at a later date.

4.1.6 2020 LWRS Plant Modernization Pathway Stakeholder Engagement Meeting

The LWRS program annually sponsors a Stakeholder Engagement Meeting, conducted on a research pathway basis. The Plant Modernization Pathway held its meeting on August 26–27, 2020, in four virtual sessions due to the ongoing COVID-19 travel restrictions, as follows:

Session 1 Pathway Overview and Integrated Operations for Nuclear

Session 2 I&C Architecture

Session 3 Data Architecture and Monitoring

Session 4 Human and Technology Integration

Each virtual session emphasized opportunities to increase engagement of the Plant Modernization Pathway with the U.S. commercial nuclear power industry, vendors and suppliers, regulators, and research organizations that focus on issues of sustainability and enhanced operational safety and economic performance of the light-water reactor industry. Each session featured presentations by utility collaborators about their ongoing projects as well as the collaborators taking questions from the audience as a panel.

This event provided a significant opportunity for industry engagement on ION with eighty-nine registrants for Session 1. Presentations included:

1. Integrated Operations—Lessons from the North Seas Oil and Gas Industry by Don Bosnic, Xcel Energy
2. Xcel Energy Nuclear—Transformation to Integrated Operations by Hank Butterworth, Xcel Energy
3. Transformational Concepts from Other Industry Sectors by Sean Lawrie, Scott Madden
4. ION Future Activities, Ken Thomas, Idaho National Laboratory

The panel discussion segment of the session addressed a number of practical considerations for implementing ION, providing additional details on how Xcel Energy has organized an internal structure to apply the ION methodologies through a development team for all major functional areas. The ION presentations are found in Appendix E.

4.2 Supplier Engagement

4.2.1 MPR Associates

MPR Associates is a multidisciplinary engineering company with a wide range of services that includes power and energy, nuclear technologies, transmission and distribution, and health and life sciences, risk management, and project management [15]. They have provided these services to the U.S. nuclear utilities for decades in highly complex engineering projects. MPR is currently involved in a number of modernization efforts for nuclear plants, including a major digital upgrade for a safety-related I&C system. MPR is also involved with the LWRS program is defining an advanced concept of operations based on I&C modernization as a key building block for nuclear transformation.

An interactive virtual presentation was conducted on September 2, 2020, with senior leaders of MPR, focusing on how suppliers can interact with and be part of implementing ION. In order for ION to be truly transformational, many traditional engineering and service functions must be conducted on an as-needed basis rather than locating a full-time expert at each plant site. MPR stated that they have begun business initiatives along these lines as well and expressed interest in working with LWRS to further promote this concept.

5. Future Engagements

Given that a full description of ION has just now become available as project results are obtained, many additional utility and supplier engagements will occur in FY 2021. Since there was great interest generated at the ANS Utility Working Conference, the LWRS program Stakeholder Engagement Meeting, and other initial presentations, it is expected that many other stakeholders will be interested in

learning more about ION. The following are upcoming opportunities and general plans for FY 2021 engagements.

5.1.1 Electric Utility Cost Group

The Electric Utility Cost Group (EUCG) is a cooperative organization that provides a professional working forum for the electric utility industry to share information to help individual companies improve their operating, maintenance, and construction performance. The EUCG helps utilities share information and benchmark against those in their class. Within the EUCG is a nuclear committee that promotes the exchange of current and relevant global nuclear power plant cost and performance information [16].

The EUCG has invited the Plant Modernization Pathway to make a presentation on ION and related developments in its annual meeting scheduled for September 25, 2020, which is being held virtually this year due to the COVID-19 travel restrictions. The utility representatives for this meeting are typically involved in performance improvement activities in their companies, and, therefore, this is a good opportunity to create awareness of the ION development and an opportunity for follow up with these companies.

5.1.2 ANS Winter Meeting

The background on ANS was provided in Section 4.1.4 above. The Plant Modernization Pathway submitted an abstract for a session presentation in this meeting to be held on November 15–19, 2020, which will be held virtually due to the COVID-19 travel restrictions. The abstract was accepted, and a paper and presentation will be developed for the assigned meeting session. This meeting is widely attended by nuclear utilities and suppliers, and it is expected that a number of these with interest in the ION concept will request follow-up as a result of this presentation. In addition, there is considerable participation by academic and research organizations, which could lead to beneficial collaborations in the continued development of the ION concept.

5.1.3 Utility Specific Engagements

Following the initial strategy of creating awareness of the ION concept through broad industry meetings and support organizations, engagement with specific nuclear utilities will be pursued. The intent is to develop cooperation among a first group of utilities that will take advantage of the results of the collaboration with Xcel Energy and continue to build on it, broadening the learnings and analysis tools through adaptation to the different needs of these companies. Most nuclear utilities have some modernization projects underway, and ION will provide a means of structuring these efforts into needed transformation of their nuclear operating models for long-term sustainability.

These will be focused presentations to early-mover utilities in modernization and innovation, conveying the ION concepts, development, and deliverables but also somewhat customized to the modernization direction for each of the utilities.

5.1.4 Supplier Engagements

Suppliers will play a key role with utilities in the transformation of the U.S. nuclear industry in a mutually beneficial way. There will be opportunities to offer new types and levels of services for technical functions that the utilities will want to outsource if the suppliers can perform them in an equivalent manner to in-house resources. This will be possible through advances in remote collaboration technology that will enable real-time job and decision support on a 24/7 basis.

This concept is currently being developed in Generation 2 of integrated operations in the North Sea oil and gas industry. It has significant advantages for nuclear utilities in that they will no longer have to develop and maintain these types of expertise in-house without losing any effectiveness. For those that are not needed on a full-time basis, the utilities will save costs by sharing those resources with other

companies. Also, the experience base for these suppliers in serving many utilities will be much broader than what it would likely be with any utility's in-house staff.

As part of the engagement strategy for nuclear industry suppliers, the Plant Modernization Pathway will conduct presentations and focused meetings on how these outsourcing service models might take advantage of emerging remote collaboration technologies. The pathway will also promote this concept among ION participating utilities with the intent of exploring common outsourcing opportunities where mutually advantageous among the utilities and suppliers.

6. Next Steps

Given the current state of the commercial nuclear industry, it is imperative that the concept and practices of IO be shared as widely as possible in order to create an industry business model for nuclear power to not only survive but to prosper. Only through the integrated efforts of utilities, suppliers, regulators, and research institutions can the full benefit of ION be realized. The Plant Modernization Pathway will seek to share these concepts with as wide an audience as possible and continue to refine the concepts as ION is implemented by various nuclear utilities. It is expected that at least two to three more utilities will be interested in beginning pilot projects in FY 2021, thereby providing additional avenues for further development of the ION co and practice.

The pathway will also consider creating an industry focus group for studies and further development of tools and concepts supporting ION. This group might involve universities, research organizations, and regulatory organizations. This group could be patterned after the successful IO Center for Integrated Operations in the petroleum industry.

7. References

1. Idaho National Laboratory Light Water Reactor Sustainability Program website, https://lwrs.inl.gov/SitePages/Home.aspx.
2. Lybeck, N., Thomas, K., Primer, C., Plant Modernization Technical Program Plan for FY 2020, INL/EXT-13-28055 Revision 9, Idaho National Laboratory, September 2019.
3. Drøivoldsmo, A., Rindahl, G., McDonald, R., Lessons Learned from Integrated Operations in the Petroleum Industry, Institute for Energy Technology, 2019.
4. Thomas, K., Remer, J., Primer, C., Bosnic, D., Butterworth, H., Edwards, C., Foote, G., Drøivoldsmo, A., Rindahl, G., McDonald, R., Lawrie, S., Baker, E., Analysis and Planning Framework for Nuclear Plant Transformation, INL/EXT-20-59537, Idaho National Laboratory, August 2020.
5. Xcel Energy corporate web site, https://www.xcelenergy.com
6. Roberts, David (2018-12-05). "For the first time, a major US utility has committed to 100% clean energy." Vox.
7. ScottMadden corporate web site, https://www.scottmadden.com
8. Grove, Andrew S., Only the Paranoid Survive: How to Exploit the Crisis Points That Challenge Every Company, Crown Publishing, 1996.
9. SPE-170630-MS Intelligent Energy: A Strategic Inflection Point Mark Lochmann, OVS Group; Ian Brown, Platts, Society of Petroleum Engineers, 2014.
10. INPO corporate web site, http://www.inpo.info
11. NRC web site, https://www.nrc.gov
12. ANS web site, https://www.ans.org/
13. NEI web site, https://www.nei.org/home
14. Nuclear Energy Institute, Delivering the Nuclear Promise: Advancing Safety, Reliability and Economic Performance, February 2016.

15. MPR corporate web site, https://www.mpr.com
16. EUCG web site, https://www.eucg.org

Appendix A
Integrated Operations for Nuclear—Project Summary

DOE Light Water Reactor Sustainability Program Plant Modernization Pathway

Integrated Operations for Nuclear

Overview

The overall objective of this research collaboration is to deliver to the nuclear industry a validated means of bringing their operating costs in line with the realities of the electric market through the transformation of their operating model—and to accomplish this through business-driven technology innovation. This will address the two major barriers to extended plant life—long-term technical and economic viability.

Collaborating with Xcel Energy Nuclear Generation in their XE1 Program, the DOE LWRS program Plant Modernization Pathway is focused on developing a business-driven approach to transforming the operating model of a commercial nuclear plant from one that is labor-centric to one that is technology-centric, as many other industry sectors have done to survive in the marketplace.

The underlying concept for this operating model transformation is known as integrated operations (IO). IO refers to the integration of people, disciplines, organizations, work processes supported by information and communication technology to make smarter decisions. Over the past two decades, North Sea oil and gas companies have implemented IO to restructure their operating models to remain profitable amid declining offshore petroleum fields and depressed oil and gas prices. Using advanced digital technologies, they moved operations and support functions onshore to serve multiple platforms, as one example of business model transformation.

Norway's Institute for Energy Technology (IFE), who sponsors the Halden Reactor Project, has been a leader in developing the principles and methods of IO as well as the technologies that enable this transformation. They are contracted as part of the project team to apply the IO learnings to the nuclear plant operating model. This past fall, they provided a new report to the Pathway, "Lessons Learned from Integrated Operations in the Petroleum Industry," based on their deep understanding of both offshore petroleum production and nuclear plant operations and support.

ScottMadden Management Consultants is also part of the project team to provide a cost benefit analysis and innovative concepts from both the nuclear and other industry sectors. In addition, Jason Remer (Remer Engineering) is part of the project team, bringing nuclear plant operational experience as well as his NEI regulatory initiative experience (digital I&C, license extension, and associated plant aging management).

The project team is working directly with the Xcel Energy XE1 program to analyze the nuclear generation work functions to derive a more efficient means of accomplishing their required outcomes through work elimination, requirement reduction, process improvement, technology application, and other forms of innovation. Through this collaboration, the Pathway is developing a framework and an accompanying tool set for the analysis and formulation of the transformed operating model, as described below.

Analysis and Planning Framework for Nuclear Plant Transformation

This integrated operations for nuclear framework is a business-driven approach for transforming the operating model of a commercial nuclear plant from one that is labor-centric to one that is technology-centric, using a top-down/bottom-up process as follows:

- A market-based price point for nuclear generation (typically the bus-bar cost in $/MWH) is set and then used to back out what the maximum total O&M budget of the nuclear fleet can be to support this price. This budget, in turn, is allocated over the nuclear organization in a top-down manner as the starting point of an iterative process. (Top-Down)
- Work functions are analyzed for aggressive opportunities to reduce workload to that which is essential and can be resourced within this O&M budget. (Bottom-Up)
- The streamlined work functions are then configured into a transformed operating model that leverages advanced technology and process innovations, resulting in a small onsite staff focused on daily operations with all maintenance and support functions centralized or outsourced in on-demand service models.

Components of the Framework:

1. Top-Down/Bottom-Up Process for reconciling the future cost of business to the future market price of electric output for a nuclear power plant.
2. Work Function Analysis Process is part of the bottom-up process, where nuclear plant work functions are individually analyzed for a cost reduction and performance improvement through the application of innovative digital technologies and process methodologies.
3. Business Case Methodology Process for adapting the Pathway previously developed business case methodology into this framework for the direct generation of investment business cases for work function innovation.
4. Catalog of Innovation concepts for work function streamlining and simplification through a wide variety of technology innovations and other cost reduction measures.

Analysis and Planning Tool Set for Nuclear Plant Transformation

This is the collection of computer-based applications that are used in the framework processes, as deliverables to the industry to conduct this integrated operations for nuclear analysis in the same manner as the collaboration with Xcel. They consist of:

1. Work Function Analysis Data Base—a repository of the information required to analyze nuclear plant work functions and apply innovative concepts to them. The information includes descriptions of the work functions, all constraints on the work functions (regulatory, policy, etc.), descriptions of work reduction opportunities for the individual work functions, quantification of labor and nonlabor savings achieved through those opportunities, and certain risk assessment information in pursuing those opportunities.
2. Technology Innovation Data Base—a repository for a wide range of information on innovative technologies applicable to nuclear power plants. This data base will be seamlessly joined to the Work Function Analysis Data Base, so that the information can be accessed and applied while conducting work function analysis. It will also be accessible in a standalone form as a web app, so nuclear utilities can access the information directly.
3. Business Case Methodology Interface—as previously mentioned, a prior Pathway project developed a business case tool (known as the Business Case Methodology Workbook [BCMW]—a complex Excel workbook) that compiles the detailed work activity savings for nuclear plant innovation and aggregates the benefits into an overall business case format, providing a calculation of harvestable savings (reduced FTE) and the present worth of the benefits. The BCMW will be interfaced, with minor adaptations, to the Work Function Analysis

Database, so that the labor and nonlabor data can be seamlessly transferred into the BCMW to produce the needed investment business cases.

Appendix B
Integrated Operations for Nuclear—Presentation

Plant Modernization Pathway

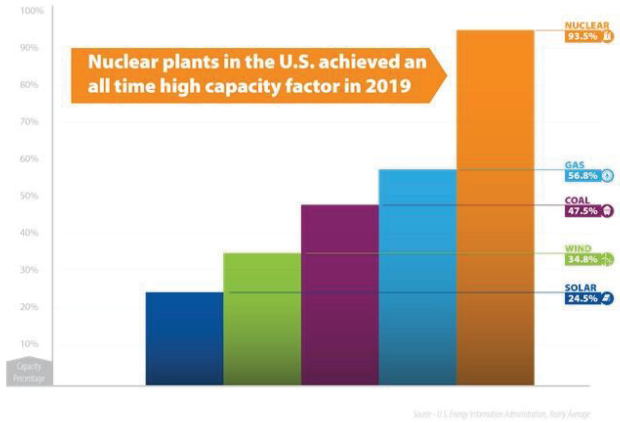
LWRS LIGHT WATER REACTOR SUSTAINABILITY

Integrated Operations for Nuclear - ION

LWRS LIGHT WATER REACTOR SUSTAINABILITY **The Good News ...**

LWRS LIGHT WATER REACTOR SUSTAINABILITY

2019 Capacity Factors by Energy Source

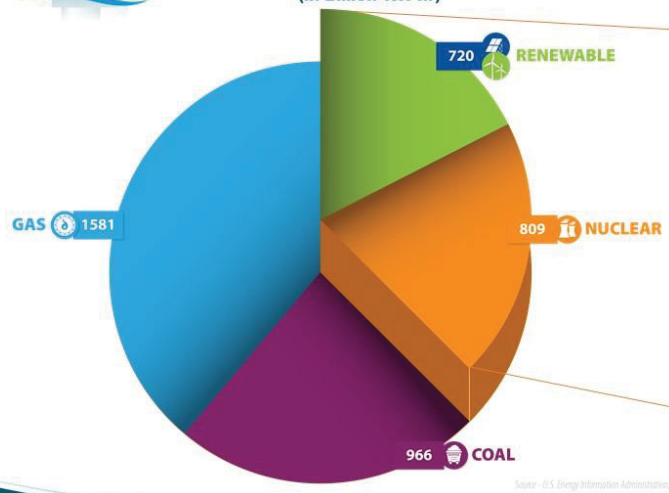


How long the power lasts in one day:

LWRS LIGHT WATER REACTOR SUSTAINABILITY

2019 Net Generation at Utility Scale Facilities

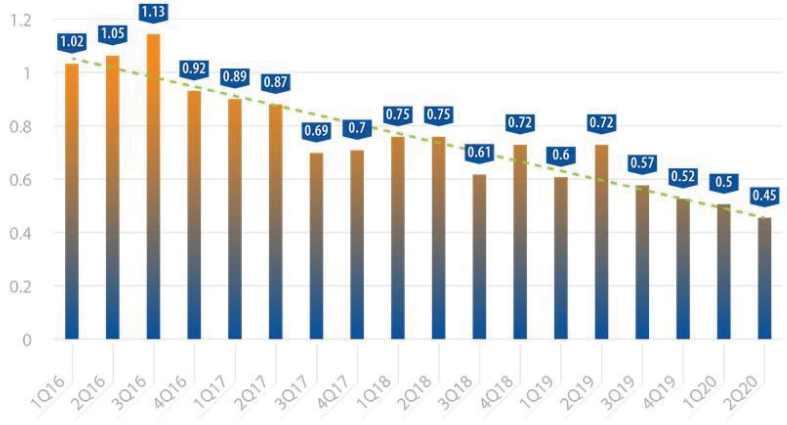
(in Billion KW-hr)



Clean Energy

LWRS LIGHT WATER REACTOR SUSTAINABILITY

ENRs per Operating Unit



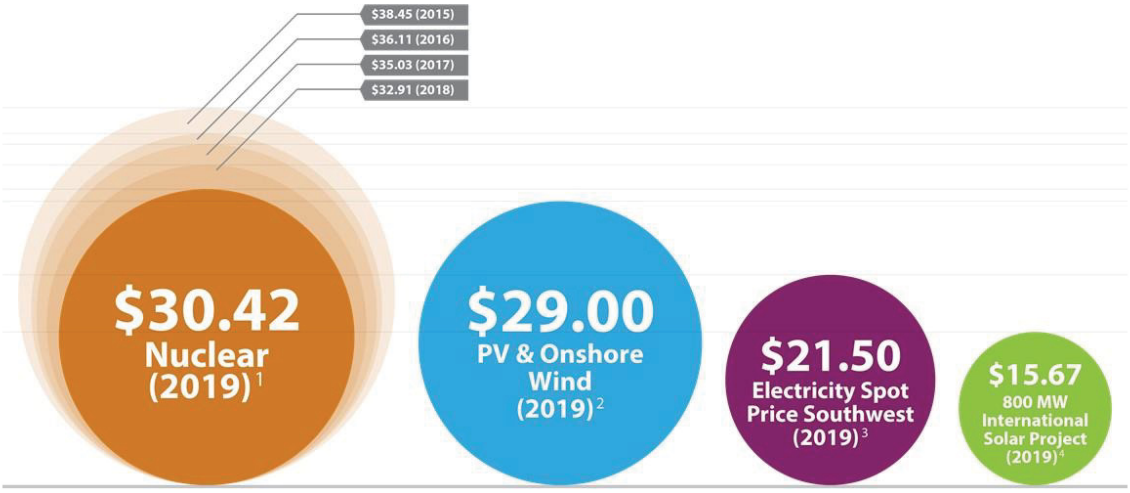
Source – NRC Event Notification Reports

LWRS LIGHT WATER REACTOR SUSTAINABILITY

The Bad News...

LWRS LIGHT WATER REACTOR SUSTAINABILITY

Total Average Operating Costs (Dollars/MWhr)



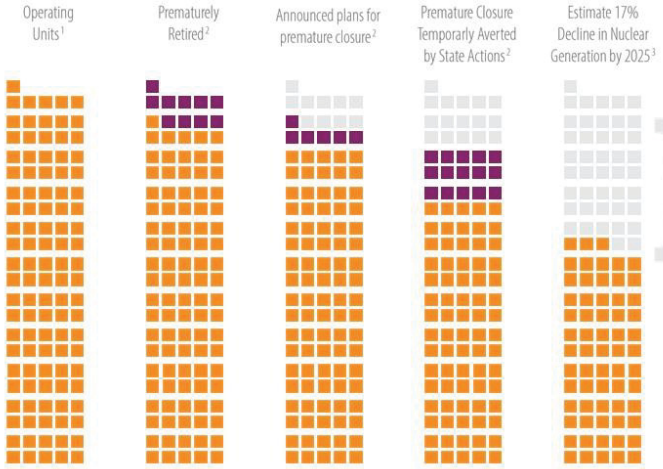
1 - Nuclear costs from Electric Utility Cost Group 2 - EIA, LCOE for New Generation Entering Service in 2022 3 - US Energy Information Administration (EIA) 4 - PV Magazine 1/23/20

LWRS LIGHT WATER REACTOR SUSTAINABILITY

Premature Closures

"These early retirements are noteworthy, since the cost to construct the reactors is sunk. Even in a market where building a new plant would be unprofitable, the continued operation of a well-maintained and operated plant might be expected to be profitable. A decision to close means the wholesale price of electricity does not even cover a plant's ongoing operating and maintenance costs, including any capital investments needed to keep the facility in safe working order."

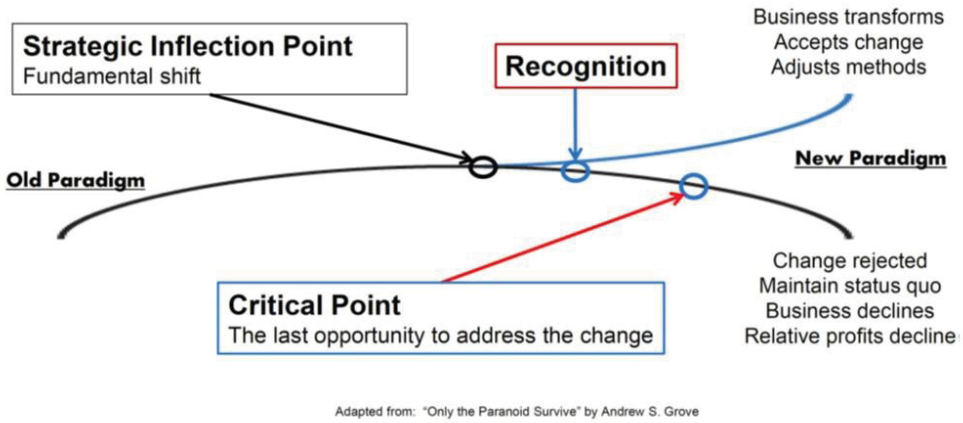
- MIT, The Future of Nuclear Power in a Carbon Constrained World



The US nuclear fleet could **shrink by over 40%** in the next **5-10 YRS** without drastic actions

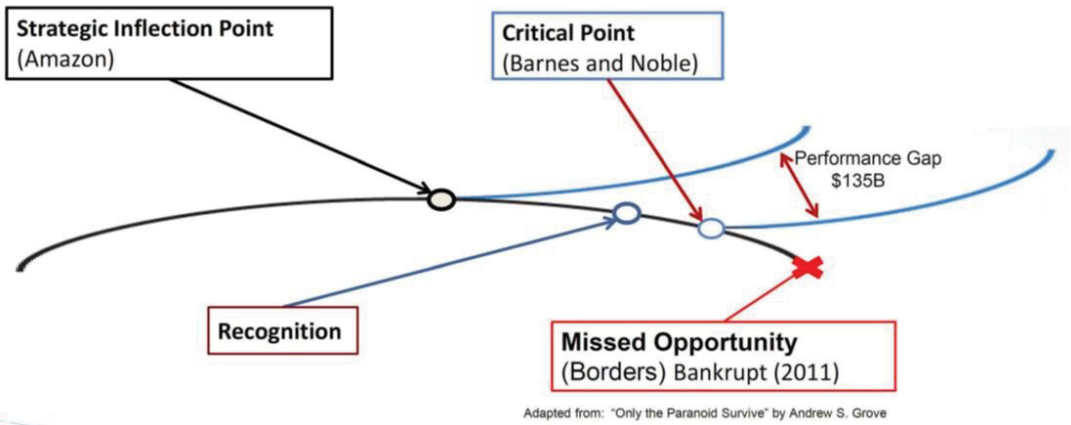
1 - As of 2013 2 - NEI Nuclear by the Numbers 3 - EIA Annual Energy Outlook 2019 ■ = 1 Unit

Strategic Inflection Point



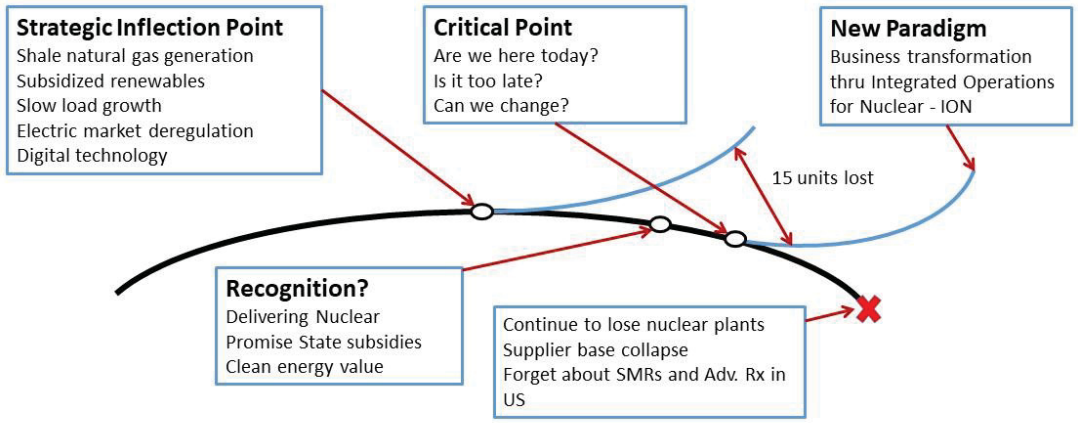
Adapted from: "Only the Paranoid Survive" by Andrew S. Grove

Strategic Inflection Point - Examples



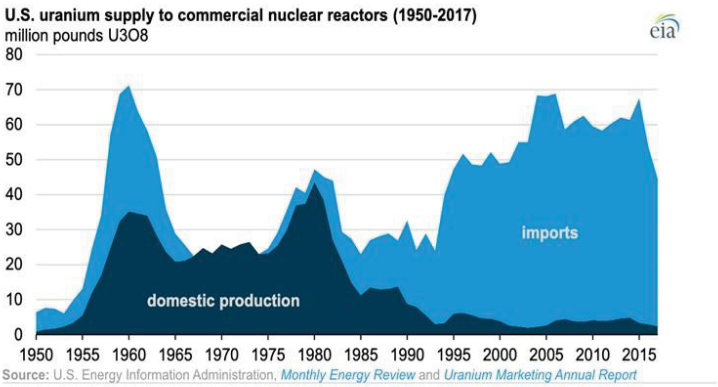
Adapted from: "Only the Paranoid Survive" by Andrew S. Grove

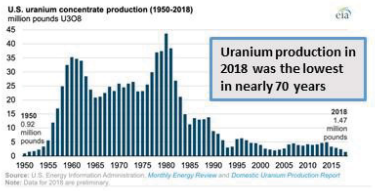
Strategic Inflection Point for Nuclear



Adapted from: "Only the Paranoid Survive" by Andrew S. Grove

US Uranium Mining Collapse





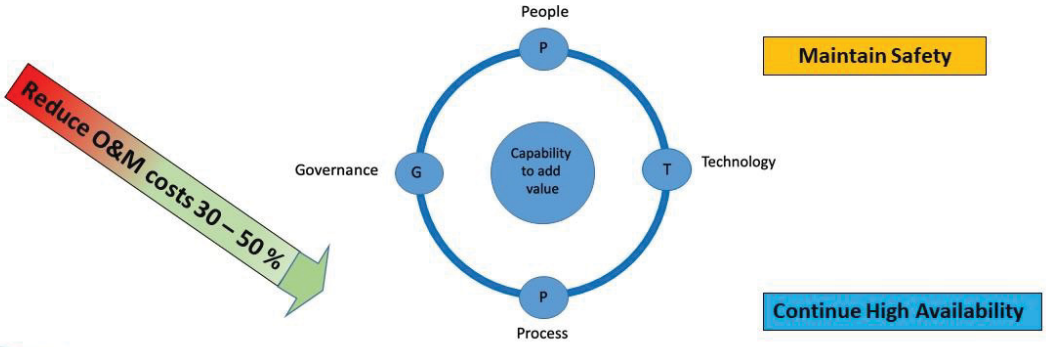
Domestic demand increased as US mining collapsed

Just now being recognized as a serious threat – delayed government action possible

What is the Answer?

The Answer – Integrated Operations

Integrated Operations (IO) refers to the integration of people, disciplines, organizations, and work processes supported by information and communication technology to make smarter decisions leading to reduced O&M costs



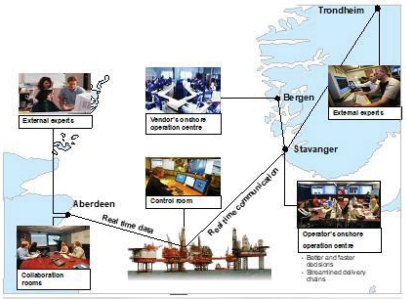
Integrated Operations Methods from the North Sea Oil Production Drive Cost Competitiveness

- North Sea oil companies implemented IO to restructure their operating models to remain profitable amid depleting off-shore oil fields and depressed oil prices.
- Using technology, they moved operations and support functions on shore to serve multiple platforms.
- Norway's Institute for Energy Technology (IFE) is working with DOE LWRS to assist in evaluating and adapting the IO methods to nuclear power operations and support.

bp British Petroleum – Field of the Future

Shell – Smart Field

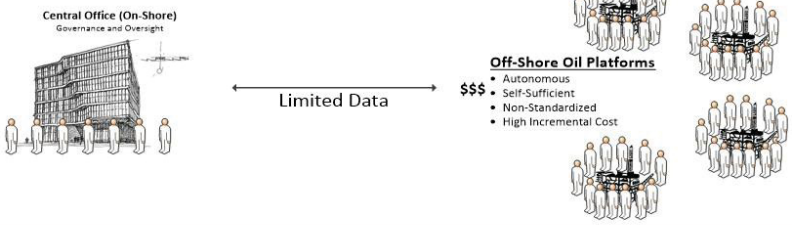
Chevron – I Field



15

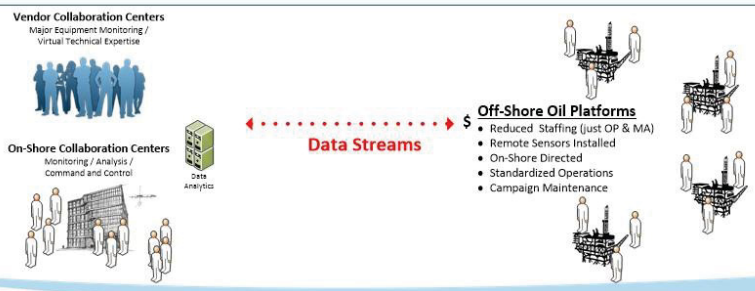
IO– How Does it Work?

Labor Centered



TO

Technology Centered



16

Integrated Operations – A Different Way of Working

Traditional Way of Working	IO Way of Working
Serial	Parallel
Single discipline	Multi discipline
Dependence of physical location	Independent of physical location
Decisions made based on historical data	Decisions made based on real-time data
Reactive	Proactive

Oil and Gas Industry Similar to Nuclear

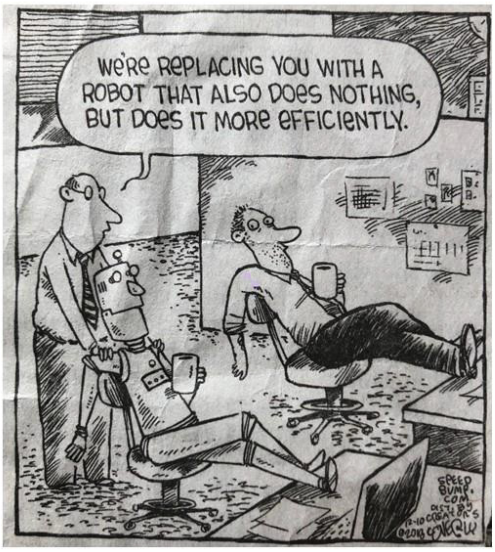
Integrated Operations – Practices

- Use of mobile resource pools
- Simplified maintenance
- Block maintenance
- Multi-skilled workforce
- Equipment monitoring
- Bring the problem to the expert
- Common Language, Infrastructure and Collaboration technology

Integrated Operations for Nuclear ION at Xcel Energy

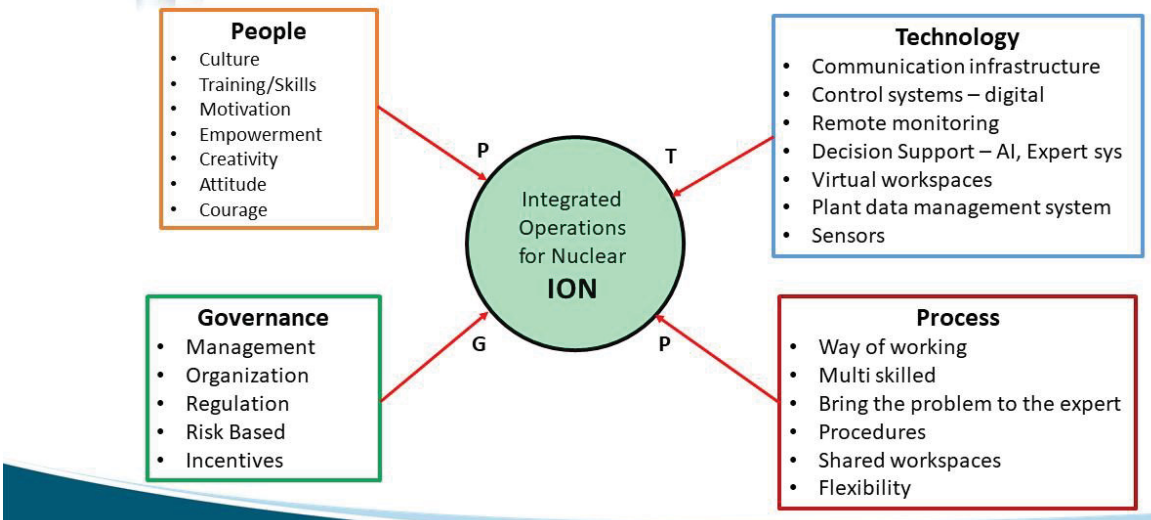
Integrated Operations is NOT about just purchasing and installing the latest and greatest technology "Solutions"

According to reports, 25 percent of technology projects fail outright; 20 to 25 percent don't show any return on investment; and as much as 50 percent need massive reworking by the time they're finished. - Forbes



Originally appeared in the Washington Post, 2019

Elements of Integrated Operations

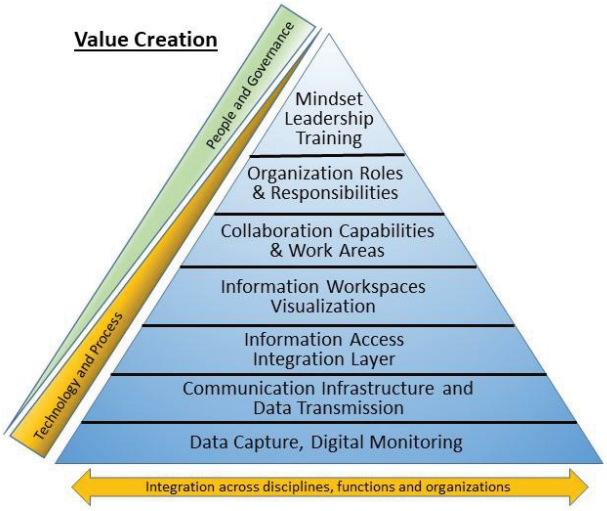


Success Criteria for Integrated Operations

"Integrated Operations …

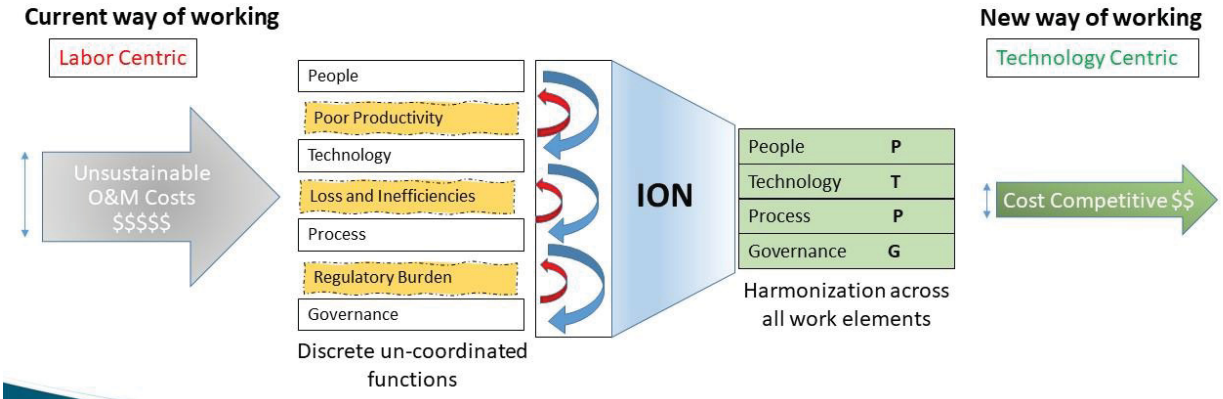
… is the integration of people, organizations, work processes and information technology to make smarter decisions.

It is enabled by global access to real time information, collaborative technology and integration of diverse expertise across disciplines, organizations and geographical locations."



Integrated Operations for Nuclear - ION

Capability Assessment and Creation



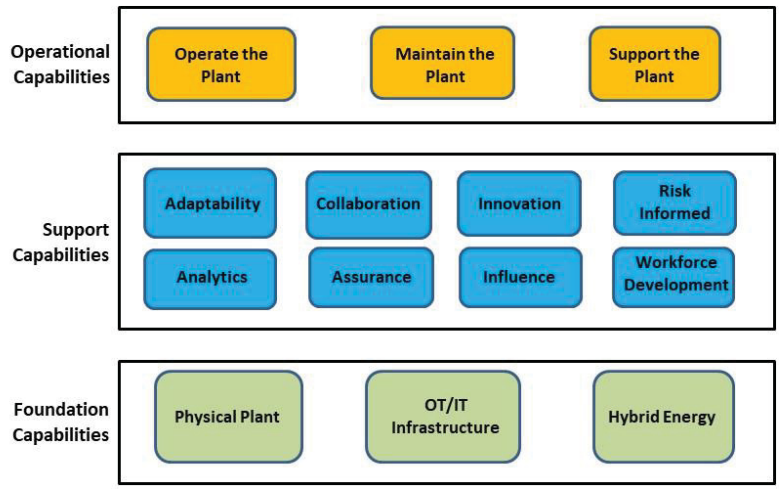
Capability Platform

Definition:

A platform that provides reusable functionality to achieve a productivity gain in subsequent innovations or applications, and second, a platform that provides an easy interface or mechanism that enables ecosystem actors to independently develop and offer distinctive functional services.

1. Creates economic options and value through design efficiency and flexibility.
2. Creates economic value though network effects generated by the ecology of organizations and individuals providing complementary goods and services.
3. Has explicit architectural control points that enable relevant stakeholders to systemically capture portions of the economic value that has been created.

Capability "Stack" Model for Nuclear



Capability Development

A planning process that focuses transformation on those core capabilities that truly define value in the eyes of the ultimate customer.

Capabilities

Principles of Execution
(how the capability works)
Platform Description
(re-usable functionality, easy interface)

Capability
- High Level Goal
- Other Goals to Be Achieved
- How Goals Are Measured
- Critical Processes
- Activities of the Critical Processes
- What the Activities Have in Common
- How the Activities Relate to Each Other

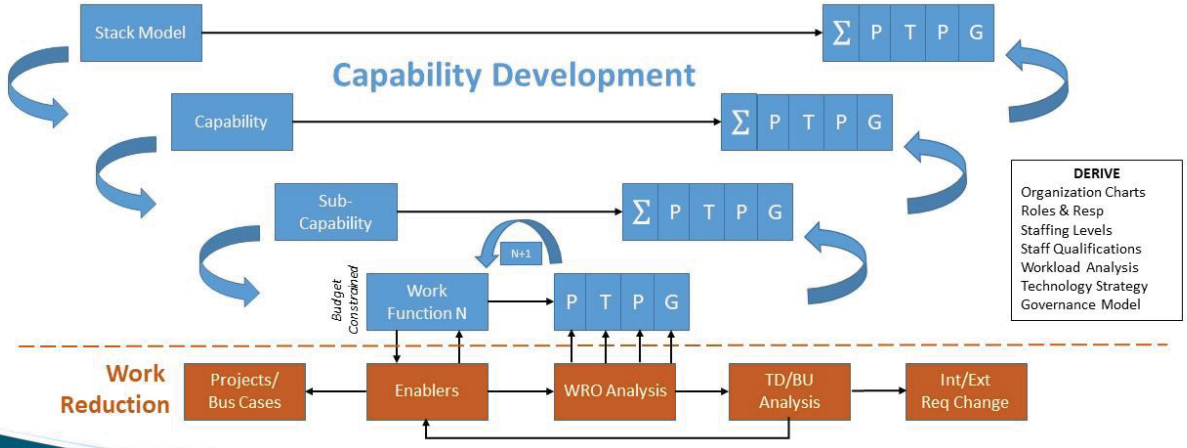
A Capability is the Synthesis of These Four Dimensions

	People	Technology	Process	Governance
		What We Need		
	Existing Resources that Can be Used			
	What New Resources Need to be Developed			

Integrated Operations for Nuclear: Framework

1. Top-Down - A market-based price point (typically bus-bar cost in $/MWH) is set and then used to back out maximum total operating and maintenance (O&M) budget to support this price.
2. Bottom-Up - Work functions are analyzed for aggressive opportunities to reduce workload within this O&M budget.
3. Streamlined work functions configured into a transformed operating model that leverages advanced technology and process innovations.
4. Resulting small on-site staff focused on daily operations with all maintenance and support functions centralized or outsourced in on-demand service models.

IO Capability and Work Reduction Opportunity

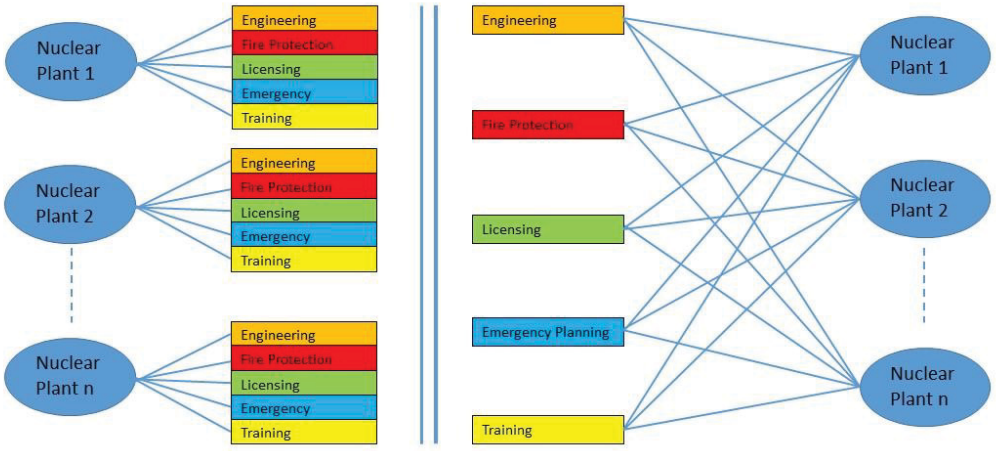


Example Principles of Execution

Operations

- Control Room staff requirements are reduced due digital automation and smart procedures.
- Plant monitoring is largely automated with advanced diagnostics and prognostics.
- Integrated risk management is highly automated, directly coupled to system and component status.
- Analytics and credit for all station resources have increased safety margins and relaxed response times (through appropriate regulatory/licensing processes).
- Data gathering is automated with sensors, field operators are cross-trained and deployed only for manual tasks.
- Paper processes have been automated (procedures, authorizations, task reviews, records, archiving, logs, etc.).
- Work management processes are transparent and self-service.
- Remote workers are closely coordinated through advanced collaboration technologies.
- Appropriate station services are outsourced where cost-effective.

Old Way of Working vs New Way of Working

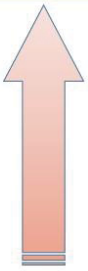


Capability Development Maturity

Structure of Capability Resource Matrix

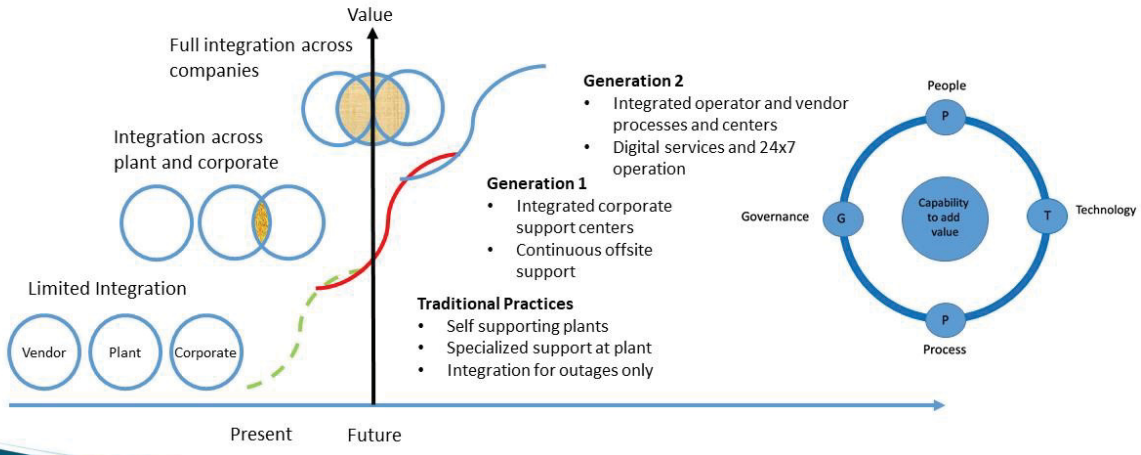
People	Technology	Process	Governance	Maturity Level
Continuous improvement and innovation of the capabilities				*Adaptable*
Predict and manage the future execution of the capabilities				*Predictable*
Scaling up proven capabilities				*Scaled*
Managing and in control of execution of capabilities				*Managed*
Delivery of the capabilities				*Initial*

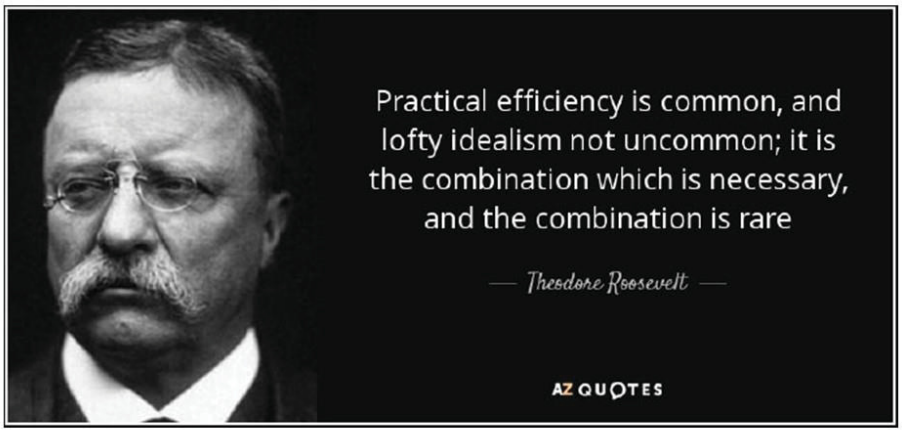
Increasing Value Creation



Adapted from: "The Capability Approach to Integrated Operations Handbook" IFE

Integration is Key to Increasing Value





Integrated Operations for Nuclear: Tool Set

ION Analysis Tool

A repository of the information required to analyze nuclear plant work functions and apply innovative concepts to them. The information includes descriptions of the work functions, all constraints on the work functions (regulatory, policy, etc.), descriptions of work reduction opportunities for the individual work functions, quantification of labor and non-labor savings achieved through those opportunities, and certain risk assessment information in pursuing those opportunities.

Innovation Portal

An interactive catalogue covering a wide range of information on innovative technologies and processes applicable to nuclear power plants. This portal will be seamlessly joined to the ION Analysis Tool so that the information can be accessed and applied while conducting work function analysis. It will also be accessible in a standalone form as a web app, so nuclear utilities can access the information directly.

Business Case Methodology Interface

The Business Case Analysis Method tool or BCAM is an integrated system to collect detailed work activity savings for nuclear plant innovations and aggregates the benefits into an overall business case format, providing a calculation of harvestable savings and the present worth of the benefits. The BCAM will be interfaced to the ION Analysis Tool so that the labor and non-labor data can be seamlessly transferred into the BCAM to produce the needed investment business cases.

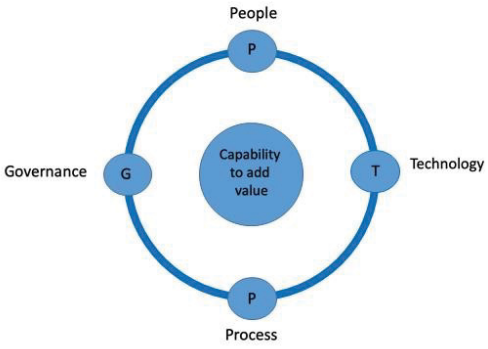
Summary

- Current fleet of nuclear plants must reduce O&M costs drastically (30 – 50%) in order to stay in business.
- State mandates are temporary and may disappear due to unforeseen circumstances.
- Clean air and environmental benefits are real, but not likely to result in additional revenue in time.
- Renewable energy continues to get less expensive.
- Natural gas will get cheaper.
- Evolutionary or continuous improvement initiatives will not deliver the necessary savings.
- What other successful safety-critical industry is still using antiquated analog II&C?
- Nuclear power is at the critical point on the SIP curve, how many more plants do we need to loose?

Excellent fleet operation and safety performance provides a solid base to launch a transformation initiative

Summary

Integrated Operations for Nuclear ION provides a roadmap and tools to transform our industry



DOE LWRS stands ready to work with industry, EPRI, NEI and vendors to bring this vision into reality.

Sustaining National Nuclear Assets

http://lwrs.inl.gov

Appendix C
Integrated Operations for Nuclear—Project Flyer

Fact Sheet

Integrated Operations for Nuclear—ION

Purpose and Objective

The purpose of this research is to deliver to the nuclear industry a validated means of bringing operations and maintenance (O&M) costs in line with the realities of the electric market through the transformation of the nuclear power plant operating model—and to accomplish this through business-driven technology innovation. The objective is the long-term technical and economic viability of the U.S. nuclear operating fleet.

Integrated Operations

The underlying concept for this operating model transformation is integrated operations (IO), which refers to the integration of people, technology, process, and governance (PTPG). This concept is implemented through a culture change, organizational restructuring, work discipline realignment, regulatory evaluation, and technology enablers. Over the past two decades, North Sea oil and gas companies have implemented IO to restructure their operating models to remain profitable amid declining offshore petroleum fields and depressed oil and gas prices.

Norway's Institute for Energy Technology (IFE), who sponsors the Halden Reactor Project, has been a leader in developing the principles and methods of IO as well as the technologies that enable this transformation. As part of the project team, they are transferring the IO knowledge to the nuclear plant operating model, based on their deep understanding of offshore petroleum production, with support from nuclear plant operations and support SMEs.

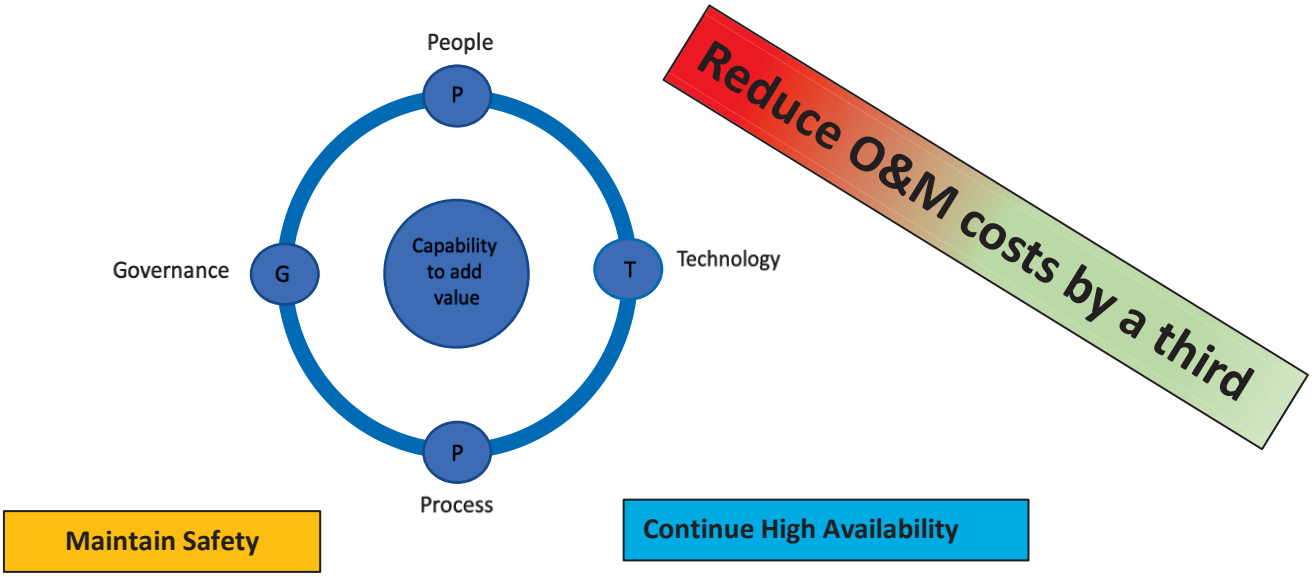
Important learnings in integrated operations from North Sea oil and gas production are being applied to the nuclear power plant operating model for long-term technical and economic viability.

Integrated Operations for Nuclear ION provides a roadmap and tools to transform our industry

Current Work

Collaborating with Xcel Energy, the project is analyzing nuclear generation work functions, considering work elimination, requirement reduction, process improvement, technology application, and other forms of innovation. The result is an integrated operations for nuclear (ION) process framework (and an accompanying tool set). The approach is as follows:

1. A market-based price point for nuclear generation is set (typically bus-bar cost in $/MWH) and then used to determine what the maximum total O&M budget for the nuclear fleet can be to support this price. This budget, in turn, is allocated over the nuclear organization in a top-down manner as the starting point of an iterative process.
2. A nuclear capability assessment (NCA) is created for each unique company and plant to determine what capabilities are required to support their business model and goals of the corporation. Capabilities that are missing or not functioning are developed or strengthened to support the planned transformation.
3. Current activities are analyzed for aggressive and visionary opportunities to reduce workload, change processes, reduce regulatory burden, or add technology so that essential work can be resourced within the target O&M budget. (Bottom-Up)
4. All transformative ideas and plans are evaluated across the four impact dimensions: people, technology, processes, and governance.
5. The streamlined work functions are then configured into a transformed operating model using integrated operations methodologies, synchronizing the interdependent resources of people, technology, process and governance, such that economic value is created.



The initial version of the **ION** process framework and tool set will be made available to U.S. nuclear operating companies in late 2020 to use in their own efforts to reduce O&M costs and modernize their operations through advanced digital technologies.

Appendix D
Abstract for ANS Winter Meeting Paper

Integrated Operations for Nuclear – ION

Kenneth D. Thomas, S. Jason Remer

Idaho National Laboratory,1955 N Fremont Ave, Idaho Falls, ID 83415, Kenneth.thomas@inl.gov
Idaho National Laboratory,1955 N Fremont Ave, Idaho Falls, ID 83415, sjr@remereng.com

INTRODUCTION

The overall objective of this research collaboration is to deliver to the nuclear industry a validated means of bringing their operating costs in line with the realities of the electric market through transformation of the operating model – and to accomplish this through business-driven technology innovation. This will address the two major barriers to extended plant life – long-term technical and economic viability.

Collaborating with Xcel Energy Nuclear Generation, the DOE LWRS Program – Plant Modernization Pathway, is focused on developing a business-driven approach to transforming the operating model of a commercial nuclear plant from one that is labor-centric to one that is technology-centric, as many other industry sectors have done to survive in the marketplace.

The underlying concept for this operating model transformation is known as Integrated Operations (IO). IO refers to the integration of people, disciplines, organizations, and work processes supported by information and communication technology to make smarter decisions. Over the past two decades, North Sea oil and gas companies have implemented IO to restructure their operating models to remain profitable amid declining offshore petroleum fields and depressed oil and gas prices. Using advanced digital technologies, they moved operations and support functions on shore to serve multiple platforms as one example of business model transformation.

BACKGROUND

Norway's Institute for Energy Technology (IFE), who sponsors the Halden Reactor Project, has been a leader in developing the principles and methods of IO, as well as the technologies that enable this transformation. They are contracted as part of the project team to apply the IO learnings to the nuclear plant operating model. This past Fall, they provided a new report to the Pathway, *Lessons Learned from Integrated Operations in the Petroleum Industry*[1], based on their deep understanding of both offshore petroleum production and nuclear plant operations and support. Fig. 1 describes some of the changes enabled by the IO process.

ScottMadden Management Consultants is also part of the project team to provide cost benefit analysis and innovative concepts from both the nuclear and other industry sectors. In addition, Jason Remer (Remer Consulting) is part of the project team, bringing nuclear plant operational experience as well as his NEI regulatory initiative experience (digital I&C, license renewal and associated plant aging management).

Traditional way of working	IO way of working
Serial	Parallel
Single discipline	Multi discipline
Dependence of physical location	Independence of physical location
Decisions are made based on historical data	Decisions are made based on real-time data
Reactive	Proactive

Fig. 1. Changes Enabled by Integrated Operations

The project team is working directly with Xcel Energy to analyze nuclear generation work functions to derive more efficient means of accomplishing their required outcomes through work elimination, requirement reduction, process improvement, technology application, and other forms of innovation. Through this collaboration, the Pathway is developing a framework and an accompanying tool set for the analysis and formulation of the transformed operating model.

FRAMEWORK FOR PLANT TRANSFORMATION

The Integrated Operations for Nuclear (ION) framework is a business-driven approach for transforming the operating model of a commercial nuclear plant from one that is labor-centric to one that is technology-centric, using a top-down/bottom-up process.

A market-based price point (typically bus-bar cost in $/MWH) for nuclear generation is set and then used to back out what the maximum total operating and maintenance (O&M) budget of the nuclear fleet can be to support this price. This budget in turn is allocated over the nuclear organization in a top-down manner as the starting point of an iterative process. This is referred to as a Top-Down analysis.

Work functions are then analyzed for aggressive opportunities to reduce workload to that which is essential and can be resourced within this O&M budget. This step is referred to as a Bottom-Up analysis.

The streamlined work functions are then configured into a transformed operating model that leverages advanced technology and process innovations, resulting in a small on-site staff focused on daily operations with all maintenance and support functions centralized or outsourced to on-demand service models.

COMPONENTS OF THE FRAMEWORK

As previously noted, a Top Down/Bottom Up Process for reconciling the future cost of business to the future market price of electric output for a nuclear power plant is used to establish a cost basis for the analysis.

A work function analysis process is part of the Bottom Up Process, where nuclear plant work functions are individually analyzed for cost reduction and performance improvement through application of innovative digital technologies and process methodologies.

In order to develop a solid justification for making the necessary investments, a solid business case must be developed and incorporated into this framework for generation of investment business cases for work function innovation.

ANALYSIS AND PLANNING TOOL SET

In order to apply Integrated Operations concepts to a nuclear utility, a set of tools is used to provide the necessary analysis and structure to undertake this major transformation.

The first of these tools is called the Work Function Analysis Data Base. This system becomes a repository of the information required to analyze nuclear plant work functions and apply innovative concepts to them. The information includes descriptions of the work functions, all constraints on the work functions (regulatory, policy, etc.), descriptions of work reduction opportunities for the individual work functions, quantification of labor and non-labor savings achieved through those opportunities, and certain risk assessment information in pursuing those opportunities.

In order to move from a labor centric model to a technology centric model, the Technology Innovation Portal has been developed as a tool to drive technology transformation and change. The Technology Innovation Portal is a repository for a wide range of information on innovative technologies and processes applicable to nuclear power plants. This portal will be seamlessly joined to the Work Function Analysis Data Base so that the information can be accessed and applied while conducting work function analysis. It will also be accessible in a standalone form as a web app, so nuclear utilities can access the information directly.

In order to drive any lasting change, investment must be made into new technology and processes. The Business Case Methodology Interface compiles detailed work activity savings for nuclear plant innovation and aggregates the benefits into an overall business case format, providing a calculation of harvestable savings (reduced FTE) and the present worth of the benefits. This system will be interfaced to the Work Function Analysis Data Base so that the labor and non-labor data can be seamlessly used to produce the needed investment business cases.

RESULTS

In order for nuclear power to survive as a competitive energy source, major structural changes must be undertaken to dramatically reduce O&M costs while still achieving excellent availability and high measures of safety. With many electric utilities announcing plans to achieve low or zero carbon generation by the middle of this century, nuclear generated electricity as a reliable, non-emitting resource must be part of achieving this goal. As stated in a 2018 MIT Report, “Premature closures of existing plants undermine efforts to reduce carbon dioxide and other power sector emissions and increase the cost of achieving emission reduction targets.”[2] In many cases, when a nuclear plant is shut down prematurely, generation is replaced not by another non emitting source, but by natural gas, leading to increasing emissions.

Integrated Operations (IO) as developed and implemented by the North Sea oil and gas industry provided a way to transform their business and achieve competitiveness despite increases in labor costs and dropping revenue. This transformation was performed while still achieving high levels of safety. Given that operation of offshore drilling and production facilities are very similar in regard to complexity, safety, and environmental impact to nuclear facilities, IO should be investigated as a possible model for transforming the nuclear industry.

CONCLUSIONS

In summary, Integrated Operations for Nuclear – ION shows promise as a model to guide the nuclear power industry in transforming to meet the current and future challenges posed by the new economic realities of power generation. It is clear that following the current course of limited technical upgrades and evolutionary process changes will not be sufficient guarantee the survival of most of the US nuclear fleet.

NOMENCLATURE

DOE – US Department of Energy
FTE – Full Time Equivalent person
I&C – Instrumentation and Control
IFE – Institute for Energy Technology, Norway
IO – Integrated Operations

ION – Integrated Operations for Nuclear
LWRS – DOE Light Water Reactor Sustainability program
NEI – Nuclear Energy Institute
O&M – Operation and Maintenance

REFERENCES

1. A. Droivoldsmo, G. Rindahl, R. McDonald, "Lessons Learned from Integrated Operations in the Petroleum Industry," Institute for Energy Technology, Halden, Norway (2019)
2. MIT, "The Future of Nuclear Energy in a Carbon-Constrained World" (2018)
3. Nuclear Energy Institute and the Electric Utility Cost Group, "Nuclear by the Numbers," (2020)
4. J. JOE, S. REMER, "Developing a Roadmap for Total Nuclear Plant Transformation," US DOE LWRS Program, (2019)

Appendix E
ANS Utility Working Conference Presentations

Integrated Operations – Lessons from the North Seas Oil and Gas Industry

Don Bosnic
General Manager – Nuclear Strategy

Xcel Energy®

ANS

Summary

- Much of our industry thinking is outdated
- There are better ways to manage our business

- We are here to talk about one of them – Integrated Operation for the nuclear power industry

Xcel Energy®

ANS

Xcel Energy Nuclear

- Xcel Energy Nuclear (NSP-MN) operates two nuclear generating sites and corporate
  - Monticello (671 MWe, BWR)
  - Prairie Island 1&2 (550 MWe, PWR)
  - Corporate Office (Minneapolis)
  - Total nuclear staff ~1000 employees

Xcel Energy®

ANS

Our Journey – How we got to this point

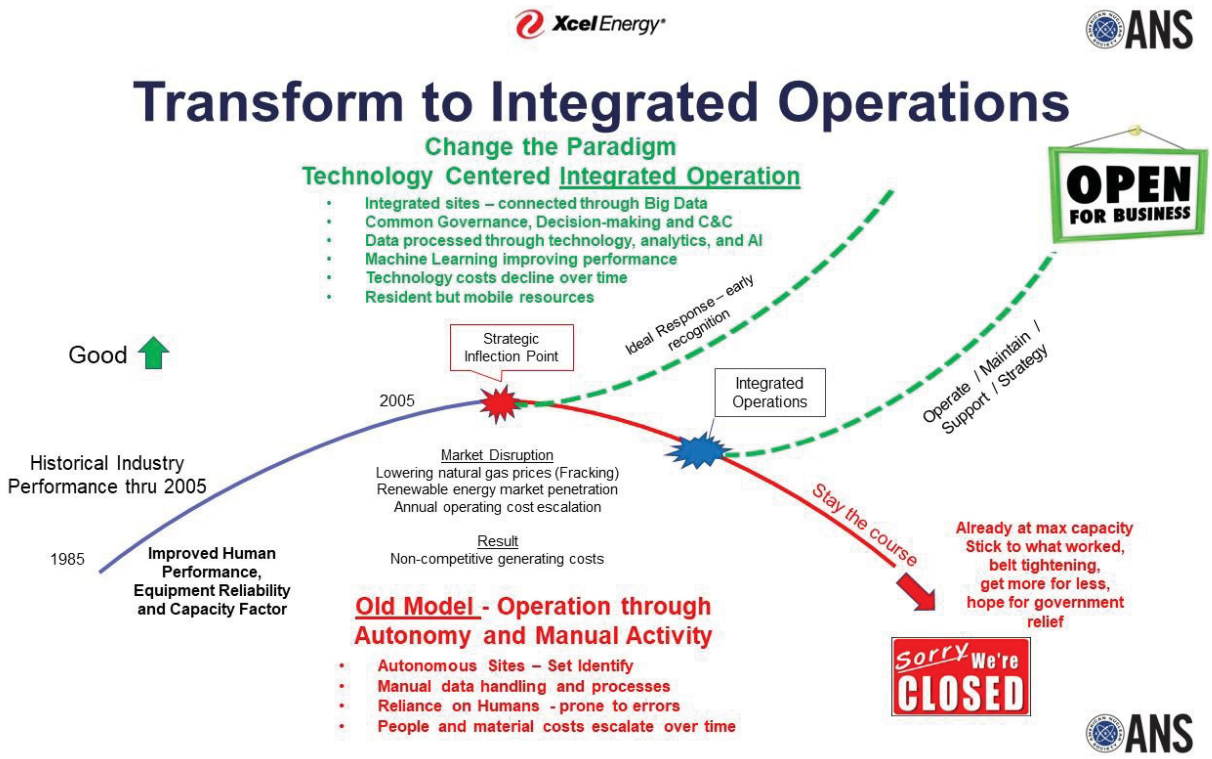
- 2015 – Focus on turning performance
  - Centralize support organizations
  - Reduced site autonomy
- 2017 – Possibility of a 100 person site - service organization thinking.
  - Focus on our core competence – Operate and Maintain
  - Connect with the best expertise for the rest
- 2018 – Functional Area Nuclear organization
- 2019 –DOE/INL/IFE connection - integrated operations model

Xcel Energy®

ANS

Why Change - Why were we drawn to this model

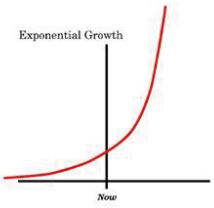
- The challenges for Nuclear are known
- To stay in the mix we need:
  - Be a top level performer (safety, reliability, consistency)
  - Be cost competitive
- Current Business Model used in nuclear is not competitive
  - DNP had some effect but didn't make us competitive
- We are at an inflection point
- We must adapt



Why Now?

- Technology supports a transformational level of communications and **connectivity**

Since 2007?



Xcel Energy®

ANS

Basic Definition - Integrated operations (IO)

- Integration of people, processes and technology to make and execute better decisions quicker.
- Information technology removes the physical boundaries between people, making collaboration and remote operation in real time possible.

Xcel Energy®

ANS

North Sea Oil & Gas Industry Comparables

- Comparable Risk and Consequence

- Both Operate as Autonomous Sites

- Technology - the Game Changer

Integrated Operations – Demonstrated Benefits

- Improved occupational health and safety
- More efficient operations
- Better reservoir and production control and optimization
- Better monitoring of equipment and more efficient maintenance
- Better resource exploitation
- Increased predictability (uptime)

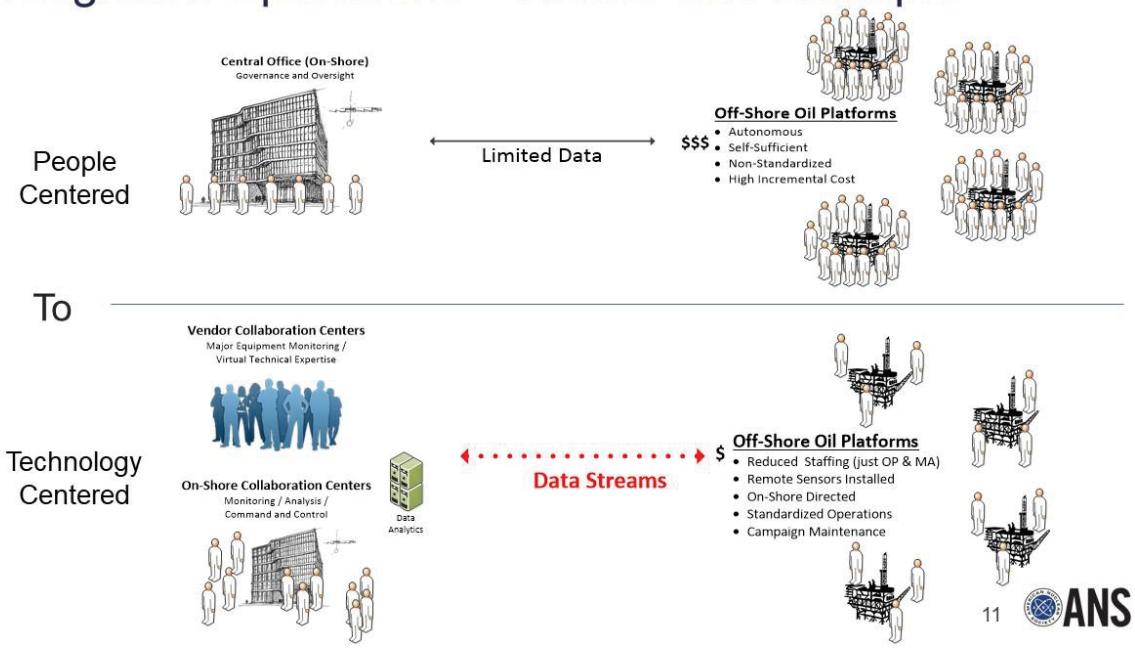
9 ANS

Integrated Operations – Basic Principles

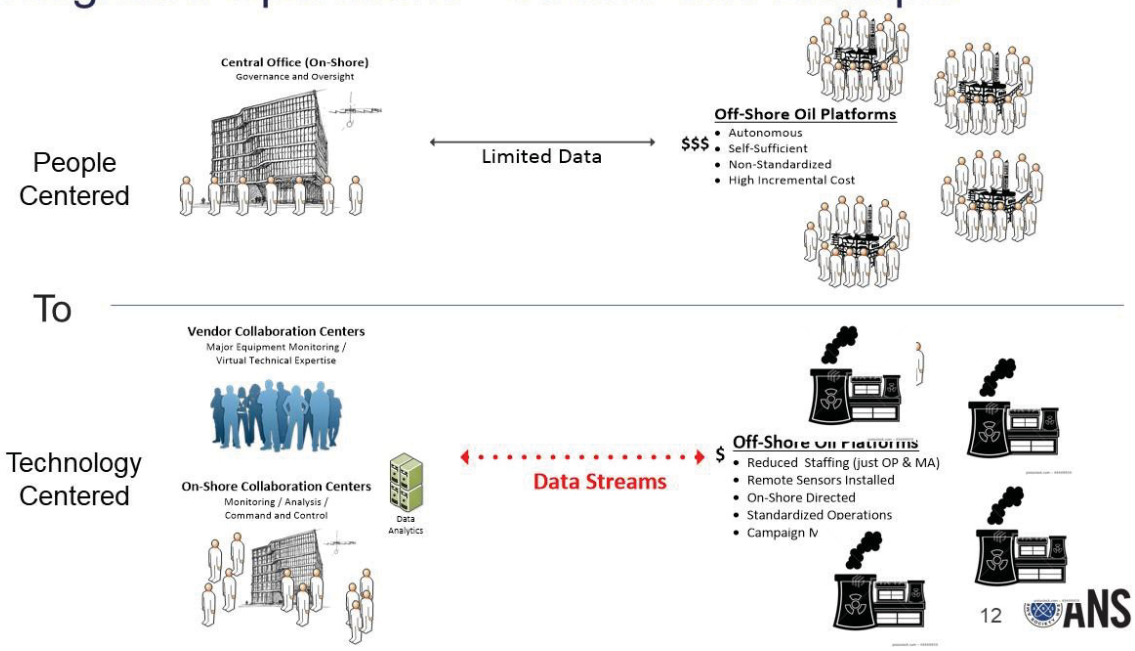
- Minimum site staffing
- Central command, decision making and monitoring with Analytics and Artificial Intelligence (Virtual organization)
- Simplified maintenance work processes
- Multi-skilled staff at the Site
- Block Maintenance
- Use of internal and external resources (remote parties support needed activities)
- Off-site monitoring by equipment suppliers/experts
- Bring the problem to the expert

Xcel Energy ANS

Integrated Operations - Oil and Gas Example



Integrated Operations - Oil and Gas Example



Benefits of integrated operations for Nuclear

- Proven - Built on years of science and research
- Preserves the essential core competencies and nuclear safety fundamentals,
- Designed to manage multiple distributed assets
- Supports scalability with addition or removal of generation units
- Drives standardization
- Strengthens industry infrastructure and stakeholder relationships
- **Improves performance and cost structure**

How will we make this change?

- The desired future state required us to expand our capabilities:
- (Examples)
  - Gathering and analyzing data
  - Communicating and collaborating between sites, technical experts, and vendors to make decisions.
  - Expanding the skills and abilities of those remaining at the sites.
  - Supporting emergent and scheduled major maintenance with remote support.
- Advancing Nuclear IO requires identifying these **capabilities**.

Xcel Energy Nuclear - Transformation to Integrated Operations

Henry (Hank) Butterworth

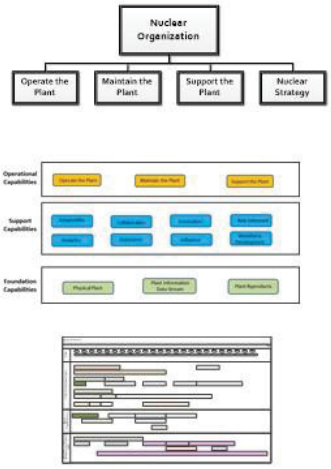
General Manager – Nuclear Transformation

Xcel Energy®

ANS

Our Approach

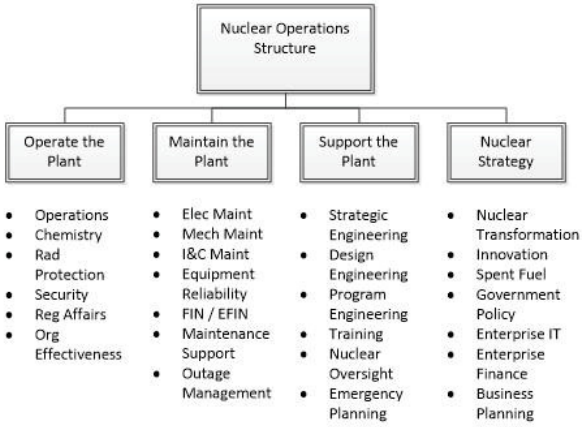
- (Top-down Analysis) Formed four functional teams to set the initial vision and structure using IO principles and challenging performance targets
- (Capability Analysis) Partnered with INL and Halden Labs to identify IO capabilities and developed a nuclear capability stack
- (Transformational Roadmap) Created a strategy to transform the business using process changes, organization changes, technology changes, and culture changes



Top-Down Analysis – First Step

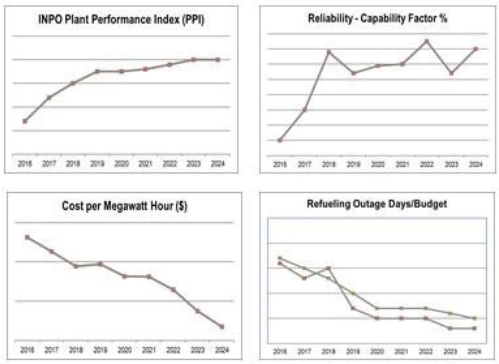
1. Getting Started

- Established Four Work-Streams (Operate, Maintain, Support, and Strategy)
- Each Group with Executive Sponsor, Top Functional Area Leaders, and Transformation Lead
- Work-Streams tasked with designing the future state while applying Integrated Operations principles

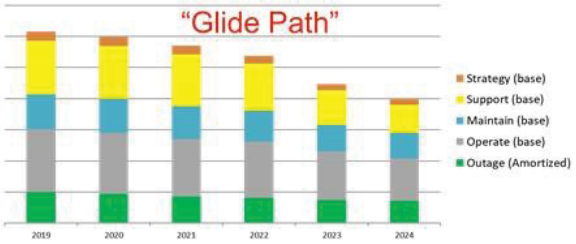


Top-Down Analysis – Setting the Target

2. *Set challenging performance goals*



3. *Translate goals into financial (O&M) targets by function*

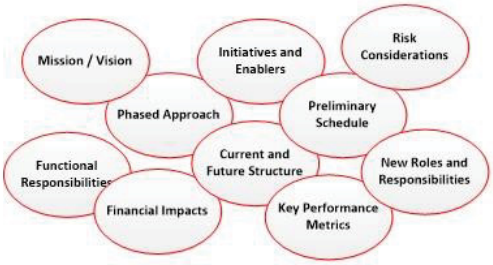


Over 30% Reduction

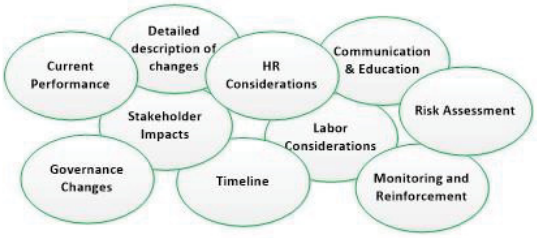
Top-Down Analysis – Developing the Plan

Work-stream Team Developed Products

4. *Developed five-year conceptual plan to meet targets*



5. *Established detailed plans to implement the conceptual plan*

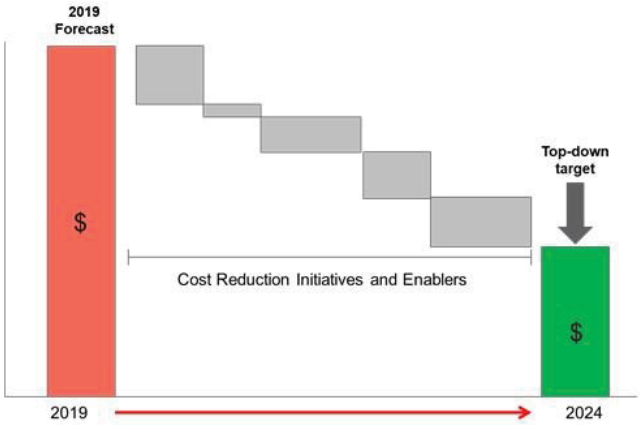


All Plans Reviewed and Approved by Executive Team

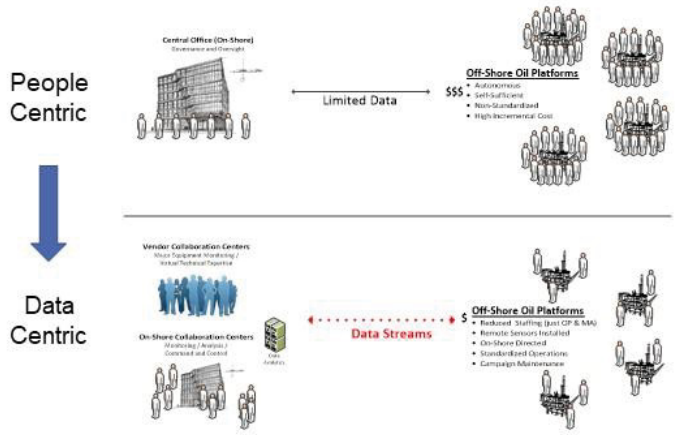
Top-Down Analysis - Benefits

Benefits

- Jump-started organizational changes (in progress)
- Identified key enablers and initiatives needed to reach the targets
- Aligned the leadership team to a common view of the future
- Started the culture change to think like an IO organization (operate / maintain / support)



Capability Analysis – Capability Definition



Capability – The ability and capacity to achieve a desired outcome.

People Centric → Data Centric

What new Capabilities were needed?

Capability Analysis - Definitions

North Seas Capabilities

Capability Stack

A structure of critical business capabilities needed to achieve the desired outcome

The North Seas Capability Structure

Capability Analysis

Assessing what new skills, abilities, process, technology, facilities and culture are needed to move to the future state.

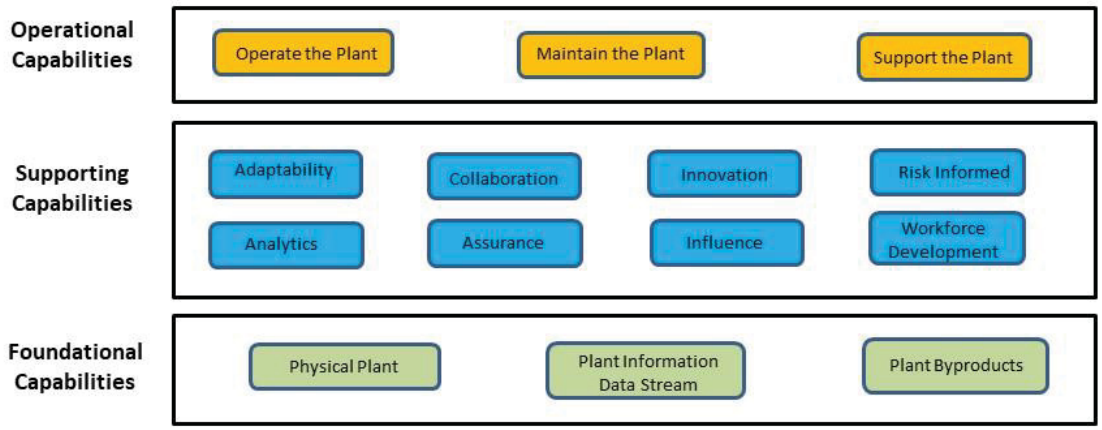
P – Process Changes

T – Technology Changes

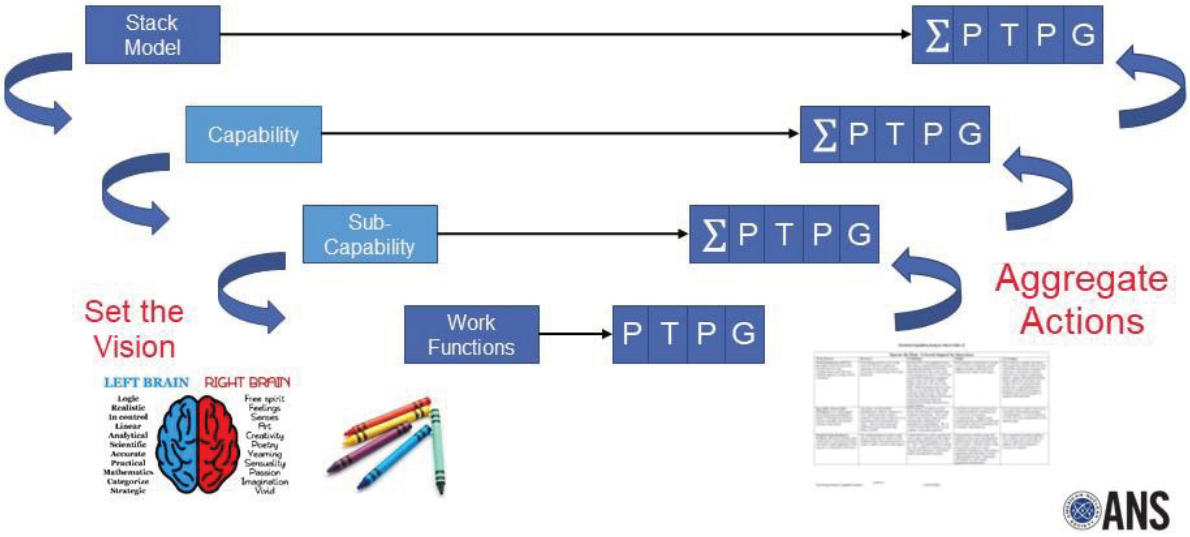
P – People Changes

G – Governance Changes

Capability Analysis – Nuclear Capability Stack



Capability Analysis Flow Path



Capability Analysis – Example

Example

- Capability – Operate the Plant
- Sub-Capability – Monitoring Plant Equipment
- Work Function – Daily in-plant operator rounds
- Future State – Automated in-plant operator rounds with anomaly detection and automated reporting

PTPG

- Process – Eliminate manual (paper) rounds collection and processing
- Technology – New remote sensors, data analytics, automated reporting
- People – Operator training on technology with new added capacity for operators doing other tasks
- Governance – changes to job functions, restructure Ops to take on new tasks.

Capability Analysis - Benefits

Benefits

- Defines future state of work functions
- Provides granularity on changes needed
- Identifies high value transformation activities
- Analysis validated many of the Top-Down assumptions

Validation of First Draft

- Reviewed by Halden Labs experts
- Impressed by rapid development of with high quality
- Suggested consolidation of some supporting capabilities
- Factor in capability maturity matrix

Transformational Roadmap – Next Steps

- Adjust organizational structure to utilize full capabilities
- Arranging implementation of technology enablers that support capability development
- Adjust work processes
- Develop talent to work in an Integrated Operations environment

Summary

- Top Down Analysis - Rapid development and transition to a new organizational structure and identification of key enablers
- Capability Analysis - detailed identification of changes to process, technology, people, and governance to achieved the desired end state
- Transformation Roadmap – Integrated plan to institute the changes needed to the organization, processes, technology and workforce.

ANS Meetings
IT'S GO TIME
Creating Momentum Toward Transformational Change

UWC 2020

Integrated Operations for Nuclear Transformation

Ken Thomas
Idaho National Laboratory

LWRS LIGHT WATER REACTOR SUSTAINABILITY

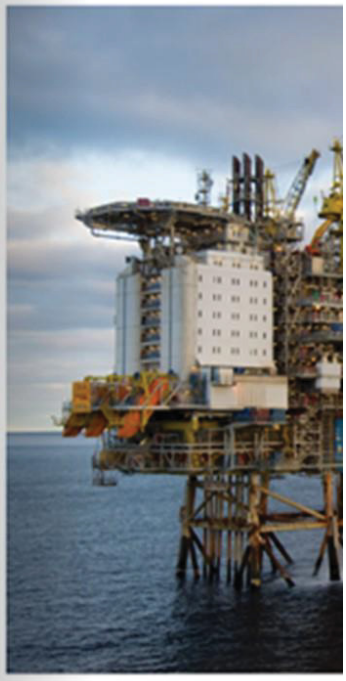
U.S. DEPARTMENT OF ENERGY
Nuclear Energy

INL Idaho National Laboratory

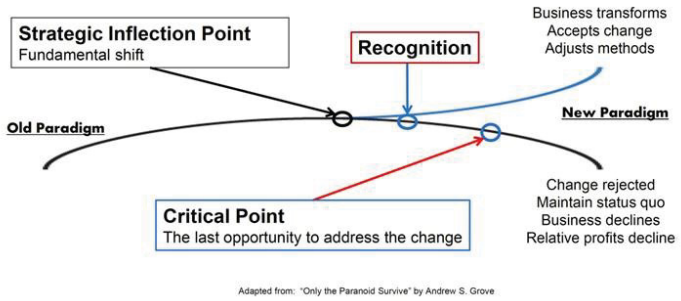
ANS

Transformation

- Transformation of the nuclear operating model through business-driven innovation.
- Enabling new ways of working for economical, sustainable plant life.
- More than modernization of plant systems and work processes.



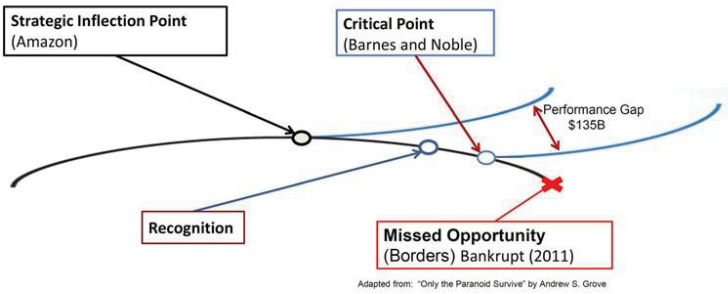
Strategic Inflection Point



- A 10X change in an element of the business
- Fundamental shift in the business or market
- What your business does now can be done in a different way
- What worked before does not work now

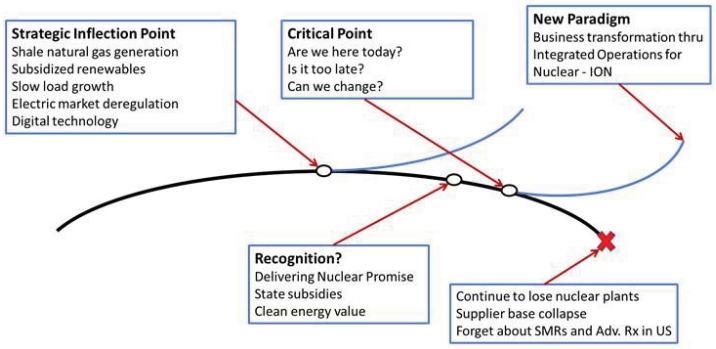
ANS

Strategic Inflection Point Example



ANS

Strategic Inflection Point for Nuclear



ANS

Special Challenges for Nuclear Transformation

- Cannot compromise nuclear safety culture
- Cannot impact power generation revenue flow
- The enormity of original physical plant assets

ANS

Requirements for Nuclear Transformation

- Proven methodology grounded in business and science principles
- Proven track record of success
- Phased implementation that ensures success and stability at every step along the transformation
- Highly effective change management plan and practices

ANS

Integrated Operations for Nuclear (ION)

- Adapting IO method to nuclear
- Applying the principles that improved North Sea profitability
- Identifying key innovation opportunities
- Developing the ION analysis tools
- Transferring this knowledge to our industry

ANS

Integrated Operations Transferable Concepts

- Lean site staff supplemented by support services on an as-needed basis
- Virtual organization – remote parties can support plant activities
- New outsourcing business models
- Campaign maintenance and plant support
- Simplified minor maintenance
- Multi-skilled workers
- Off-site monitoring by equipment suppliers/experts

ION Tools Transferable to the Industry

- Methodology Report
- ION Analysis Data Base
- Innovation Portal
- Interface to EPRI Business Case Analysis Method (BCAM)

Future Opportunities

- Updates on project results
- Utility-specific meetings for applicability
- In-depth methodology workshops for early adopters
- Information on potential new roles for suppliers

Questions

Contact:

Ken Thomas
Idaho National Laboratory
kenneth.thomas@inl.gov
919-909-5231