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Light Water Reactor Sustainability Program

Integrated Operations in Nuclear: A Strategic Approach Addressing Workforce Attraction and Knowledge Retention

Zachary Spielman and Jason Remer
Idaho National Laboratory
Asgeir Droivoldsmo, Trond Lilleng, and Øyvind Mydland
Institute for Energy Technology

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Idaho National Laboratory
Light Water Reactor Sustainability
Idaho Falls, Idaho 83415

http://lwrs.inl.gov

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ABSTRACT

The recognition of nuclear power as a cornerstone in achieving net-zero emissions by 2050 has prompted a commitment to triple nuclear-generated power and extend the operational lifetime of current plants. The 28th Conference of the Parties (Department of Energy 2023) and studies (MIT 2018) acknowledge nuclear as the most cost-effective means to these ends, maintaining high-density, dispatchable energy. This has spurred support for the legacy nuclear fleet to potentially double its operational lifespan, necessitating modernization to integrate modern technologies for sustainable and cost-effective operation. Performance indicators over the last two decades demonstrate nuclear's reliability. However, increasing complexities and rigidity in work processes signal a need for a new operating paradigm, inspired by Integrated Operations in the oil and gas industry and adapted to nuclear as Integrated Operations in Nuclear (ION). ION, within the Light Water Reactor Sustainability (LWRS) plant modernization pathway, aims to shift the nuclear fleet from a labor-centric to a data-centric business model. The focus of this report is on ION's third goal, "Worker Attraction and Retention," a pressing concern given the multi-generational workforce's varying expectations and the industry's attrition challenges. The nuclear industry is experiencing attrition at both ends of the workforce spectrum, with early-career employees leaving for better work-life balance and advancement opportunities, and a retiring workforce taking with them invaluable tacit knowledge, thus threatening operational success and safety. Modernization offers a twofold opportunity: enhancing the work environment to attract and retain next-generation workers, and leveraging technology advances in communication, data, and process automation to capture organizational knowledge. This report discusses how ION serves as a framework for incremental modernization, fostering a business model that not only adapts to market and technology fluctuations but also appeals to the next-generation workforce. It examines strategies to attract and retain talent, including transitioning to digital instrumentation and control systems, upskilling, and fostering a culture of trust and innovation. It emphasizes the importance of knowledge retention through mentorship, advanced training, and ensuring information accessibility, aligning workforce development with modernization efforts, and documenting newly required skills and knowledge in a rapidly-evolving industry.

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ACRONYMS

I&C	Instrumentation and control
IAEA	International Atomic Energy Agency
ICT	Information and Communication Technology
INL	Idaho National Laboratory
IO	Integrated Operations
IOC	Integrated Operations Center
ION	Integrated Operations in Nuclear
KPI	Key Performance Indicators
LWRS	Light Water Reactor Sustainability
NEI	Nuclear Energy Institute

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1. INTRODUCTION

Nuclear power is recognized as a key tool for achieving net-zero goals by 2050, with commitments to triple nuclear power generation (Department of Energy, 2023). The 28th Conference of the Parties also recognizes the importance of extending the lifetime of current nuclear power plants that are operating safely, sustainably, and securely. While many other clean energy technologies exist, investing in nuclear offers the lowest-cost option for achieving our net-zero goals (MIT 2018) while also maintaining high-density dispatchable energy. As a result, the legacy nuclear fleet is receiving support to continue operating and potentially double its original expected operational lifetime. This poses both challenges and opportunities to the nuclear industry, but plants must be updated to take advantage of modern technologies and transform into a sustainable and cost-effective source of safe, secure, and clean dispatchable power.

Nuclear power has a remarkable performance history in the last two decades, demonstrating that it is a highly reliable power source in terms of capacity factor, scram rate, forced loss rate, fueling outage duration, and overall cost performance (Thomas et al. 2020). However, this performance curve is approaching a level of diminishing returns (Figure 1, left). In addition, the means employed to achieve better performance are reported to increase work complexity, workload, and procedure and process rigidity (Thomas and Hallbert 2013). When this issue was discussed in 2013, a new operating paradigm was posed as the solution to accelerate nuclear operations into an era of sustainability, cost-competitiveness, and advanced ways of working by embracing modern technologies to reduce workload, manage routine tasks, and redefine jobs within the nuclear plant (Figure 1, right). What emerged as a solution was learned from the North Sea oil and gas industry and referred to as Integrated Operations (IO). It has since been adapted for nuclear power and termed Integrated Operations in Nuclear (ION).

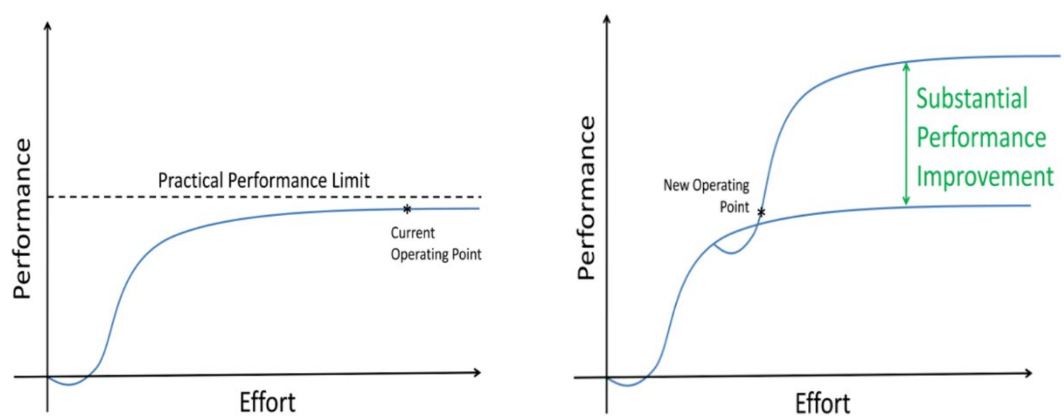

Figure 1. Graphical representation of practical performance limit if continuing current operational improvement methods (left) and potential for operational improvement by switching to another paradigm (right).

ION is now an endorsed framework within the Light Water Reactor Sustainability (LWRS) plant modernization pathway. The plant modernization pathway is dedicated to helping legacy nuclear power plants in the U.S. modernize their plant processes and operational paradigms. The goal is to transform current nuclear plant business models to sustainably and cost-effectively continue operations through a second "lifetime," or up to another six decades of generating clean power. ION is focused on transitioning the nuclear fleet from a labor-centric business model to a data- or technology-centric business model that supports improved performance at lower cost (LWRS 2024). ION supports the three objectives of the plant modernization pathway as shown in Figure 2. However, the focus of this report is the third goal, Worker Attraction and Retention, which has recently become a highly recognized issue for the nuclear industry (Remer et al. 2023).

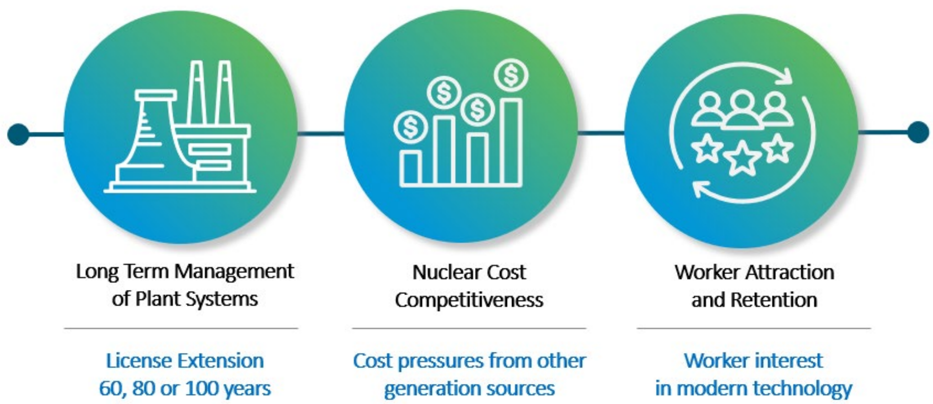

Figure 2. Light-water reactor sustainability plant modernization goals.

The contemporary workforce is uniquely multi-generational, which presents both opportunities and challenges. With a broad range of ages comes a diverse set of technological skills and work preferences, from seasoned veterans experienced with legacy systems to younger employees who prioritize work-life balance, creativity, and flexibility (Figure 3. Generational characteristics). This age-related diversity has the potential to foster innovation, as younger workers' ideas are honed by the wisdom of older workers. However, if not managed effectively, the differing expectations and competences across generations can lead to tension within the workplace. The younger generation's preferences may clash with the established, rule-heavy culture of legacy operations, which often require adherence to strict schedules and deep knowledge of specific analog or hybrid systems.

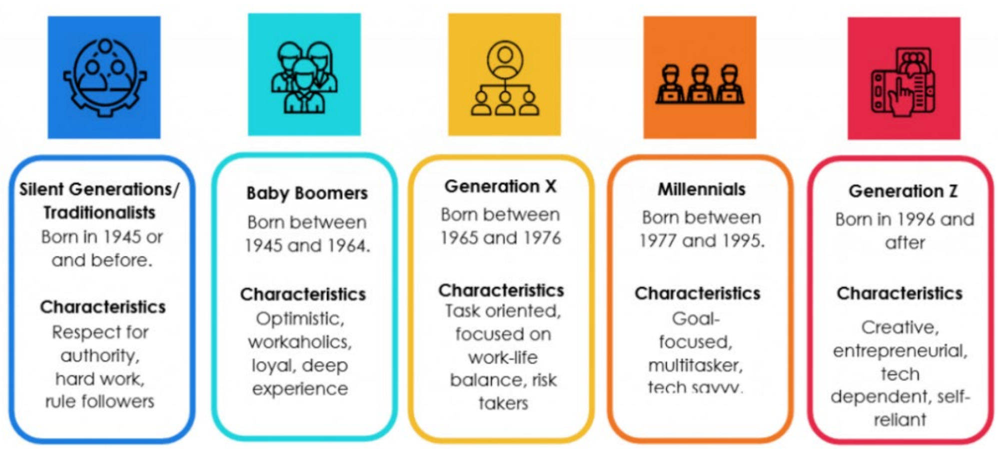

Figure 3. Generational characteristics.

The multi-generational distribution of employees in the nuclear industry is shown in Figure 4. The nuclear industry is currently experiencing attrition at both ends of this spectrum. Early career employees, often defined as those in the first ten years of their career, are seeking opportunities that better fit their values and expectations for how work is performed, and better work-life balance. This attrition rate is generating problems with hiring new skilled employees and replacing the workforce that is retiring. The retiring workforce at the tail end of the distribution is also generating issues for the industry beyond finding their replacements. The legacy workforce, with their deep knowledge and expertise as well as a willingness to work long hours on shifting schedules, are exiting without sharing their tacit knowledge for success in the workplace. The lack of both worker attraction and knowledge retention in the industry is poised to have detrimental effects on the viability of continuing legacy operations with historic success and safety.

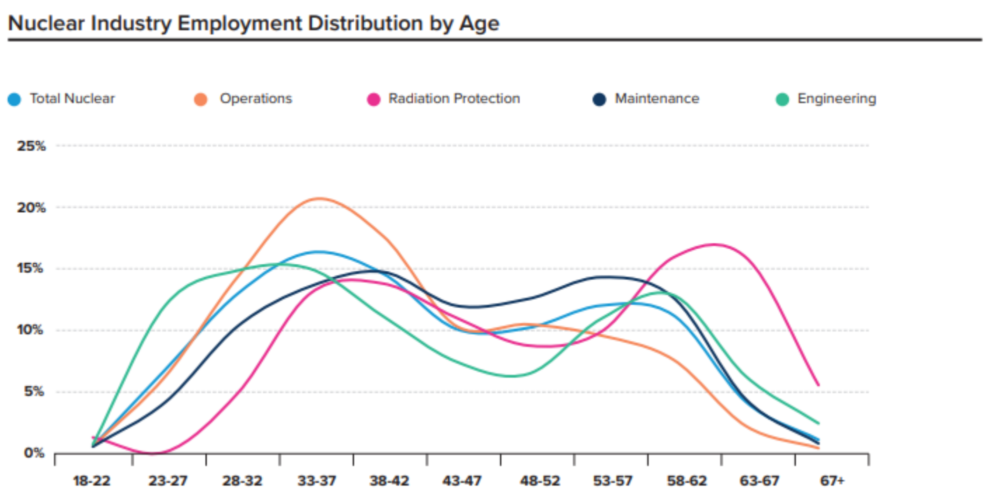

Figure 4. Nuclear industry employment distribution by age.

Fortunately, modernizing equipment, technology, and processes to continue legacy operations offers an opportunity to improve a plant's working environment to better meet the expectations of the next-generation workforce, while also lowering the cost to operate. A survey performed by Hall et al. (2023) revealed that advancing technology use and process control in the nuclear industry will help legacy plants attract and retain employees. Also, the advances in communication, data automation, process automation, artificial intelligence (AI), and collaboration strategies offer solutions to help capture and maintain organizational knowledge, both explicit and tacit.

The LWRS plant modernization pathway has investigated the suspected causes and reviewed industry reports, survey results, current data on hiring attrition, and market composition of nuclear workers to determine how modernization efforts can support workforce and knowledge retention challenges faced by the nuclear industry. Many proposed solutions can be considered to take place "outside the fence," referencing the security border of a nuclear power plant. Outside-the-fence solutions are focused on raising awareness of nuclear energy careers, creating training and education pipelines tailored for work in nuclear power, and other STEM outreach efforts. These efforts are important and must be supported, however, they fall outside the scope of LWRS. LWRS, therefore, is focused on "inside-the-fence" efforts. Inside-the-fence focuses on challenges that can be addressed through modernization efforts, such as transitioning to digital instrumentation and control (I&C), implementing modern technologies to collect, analyze, curate, and deliver information to people, and ultimately change the way work is performed at a nuclear plant. The following report discusses how plants or fleets can use the ION framework to approach modernization through incremental steps to build a business model that is not only more adaptable to fluctuating energy markets and technological opportunities but creates a work environment that the next generation of employees will be attracted to and remain at for the long term.

1.1 Workforce Attraction and Knowledge Retention

Based on a report from the Nuclear Energy Institute (NEI) titled “Nuclear Energy Industry Workforce Strategic Plan,” nuclear energy staffing consists primarily of workers nearing retirement and early-career employees, typically defined as those within the first 10 years of starting their careers (Figure 4). There is natural attrition from the group nearing retirement, as is expected. However, what is concerning is an increasing trend in attrition from the early-career workforce. A 2022 North American Young Generation in Nuclear report found work-life balance was the top reason for seeking new employment, followed closely by lack of advancement and growth opportunities, and work culture and leadership style differences (Smyth et al. 2022). The NEI report proposed, among other suggestions, developing a more modern and innovative working environment, one that better aligns with the education and expectations of the next-generation workforce. They cited such solutions as implementing digital I&C, as well as developing an infrastructure for innovation and pipelines for employees to create new solutions to their work challenges and implement them successfully. The inside-the-fence solutions to workforce attraction and knowledge retention simultaneously address the other two main drivers for an ION business transformation (cost competitiveness and life extension). They also prepare the industry for a paradigm shift in the way of collaboration and cross disciplinary working.

The newer generation often leave for career opportunities that they perceive to offer better prospects for applying and developing their professional skills, as well as achieving a more favorable work-life balance. The table in Figure 5 shows a rising trend in voluntary attrition from the early-career workforce.

	2020	2021	2022
Total Industry	**5.9%**	**7.9%**	**9.2%**
Operations	4.1%	5.2%	7.0%
Engineering	6.9%	9.0%	12.8%
Maintenance	5.1%	6.1%	6.1%
Rad Prot/Chem	7.1%	9.7%	8.9%
Security	8.0%	11.7%	15.6%
Planners/Work Week Mgrs	5.1%	8.1%	5.3%
Training	5.8%	8.8%	8.7%

Figure 5. Attrition rates within the nuclear industry broken down by organization.

This is a concerning trend for the legacy nuclear energy workforce. However, another factor may exacerbate the current attrition trends: the increase in hiring demand from new advanced nuclear plants expected to come online within a decade of the writing of this report. An estimated 100,000 people are currently employed by the nuclear power industry. The aggressive support to accelerate nuclear development is forecasting that more than three times that number (NEI 2023) will be required to sustain an advanced nuclear industry, creating a competitive workforce environment that may entice experienced and early-career employees away from legacy nuclear.

The skewed workforce composition and rising attrition has another significant consequence, that is, lack of knowledge retention in the industry. When discussing knowledge retention in this context it is useful to consider both explicit and tacit knowledge. Explicit knowledge is communicated through training, education, and procedure. It is generally considered to be easily retained and transferable through the mediums mentioned. Tacit knowledge, however, is more difficult to transfer, and is related to how high performers achieve their success and come to be considered experts. When employees leave an organization, they often take their tacit knowledge with them in the form of skills, ideas, and experiences for performing their job. A 2018 study of knowledge loss found that 42 percent of the knowledge a single employee has regarding how to perform his or her job is unique to that individual (Panopto 2018). The cost of losing this knowledge can be high, and organizations that lose tacit knowledge may face detrimental consequences, such as loss of expertise, reduced efficiency, decreased innovation, and less effective decision making. Creating attractive work environments and implementing knowledge retention strategies are therefore crucial for the continued success of the legacy nuclear industry.

1.1.1 Next-Generation Workforce Attraction

As plants modernize and the nature of functions within them evolves, it is crucial to account for subsequent changes in required knowledge, skills, abilities, and work culture for workforce attraction. The incoming generation of professionals brings with it distinct expectations of what constitutes quality work life and how they wish to contribute to the organization. Achieving a modern and innovative workplace is possible through advancements in people-technology interaction and the capability to streamline processes while simultaneously collecting data that can inform data-driven decisions and innovations. This approach is pivotal for efficient labor utilization.

Transitioning to an ION business model can alleviate many of these challenges and create a working environment that both improves work processes and addresses the needs and priorities of the next-generation workforce. The move towards centralizing resources and enabling remote operations not only brings employees closer to urban centers, offering a better work-life balance, but also fosters a collaborative work environment that crosses different disciplines and organizations. This paradigm shift requires the modernization of I&C systems to ensure enhanced data transfer and communication capabilities.

Such a transition in the workplace also mandates upskilling, with expertise aligning more closely with the kind of education being imparted today, which is more digitally focused and innovative. The more modern ION approach naturally flattens the traditional hierarchical structure prevalent in most plants, empowering employees at various levels to become decision-makers and execute tasks with greater efficiency. Also, experiences from the North Sea O&G show that an expert engineer operating within an IO framework may be exposed to more cases and challenges within a five-year period compared to an engineer throughout her entire working career in a traditional company structure and way of working. The exposure to more experience early on and at a faster pace allows for accelerated career development.

Building trust within the organization so that any problem identified can be effectively addressed is key to fostering a positive, innovative culture. This requires establishing processes that employees have confidence in. Additionally, there is a need for developing a collective mindset that ensures all members of the organization feel that their work is contributing to a unified goal. This comprehensive strategy not only enhances operational efficiency, but also nurtures a culture of trust, innovation, and shared purpose.

1.1.2 Knowledge Retention

As the legacy workforce departs, taking with them tacit knowledge essential for successful nuclear operations, it is imperative to modernize the transition of skills, knowledge, and abilities to the new generation through knowledge retention strategies. A modern approach should include establishing mentorship roles for experienced personnel, employing advanced training techniques, and ensuring that information is readily accessible at the point of work. Additionally, aligning external organizations that offer training programs prior to entry into the energy workforce with internal training requirements will further strengthen the skill base and preparedness of new employees, addressing the knowledge gap left by retiring legacy workers.

The transition towards ION emphasizes digital communications and remote meetings, which presents a unique set of challenges for maintaining team cohesion. It underscores the necessity for alternative strategies to capture, retain, and share tacit knowledge, as well as to instill desired cultural behaviors within the organization. This entails a clear definition of roles, responsibilities, and authority boundaries, which can potentially improve psychological capital among team members by providing clarity and reducing uncertainty.

To support this new approach, it is essential to establish team structures that dismantle traditional boundaries, fostering a more fluid and collaborative environment. Additionally, managing conflicts and aligning geographically diverse teams requires a concerted effort to ensure local goals are in harmony with the organization's overarching objectives. Cultivating a common language that avoids jargon or institution-specific terminology can help make communication more inclusive and accessible, thereby solidifying a common cultural language. Also, engaging all stakeholders in the establishment of ground rules and expectations is a critical step, which must be followed by targeted training and the promotion of ION awareness to ensure everyone is aligned and proficient in the new operational ethos.

With the transition towards a more interconnected and open organizational structure, there is greater access to shared knowledge and learnings across all units. Leaders in operations must be adept at recognizing when it is appropriate to lean on the expertise of others, or alternatively, when there is an opportunity to develop their own skills to effectively address challenges. This dynamic approach requires a balance of humility and ambition, driving a culture that values continuous learning and collaboration.

The flip side of knowledge retention when modernizing a plant is documenting the new skills, tasks, jobs, and functions that will be required using contemporary technology, data analytics, and remote-collaboration techniques. As the workforce transitions, plants must be cognizant of the tacit knowledge that is accumulating and document all applicable learnings in a comprehensive but easily digestible manner. Whether capturing new tacit knowledge or retaining and transferring tribal knowledge, many of the strategies are the same. Video trainings, dynamic procedures, job shadowing, and transitioning experienced employees to dedicated (part-time) mentors for newer employees are all part of the recipe for retaining tacit knowledge and maintaining high performance within the nuclear industry.

1.2 Transitioning the Workforce

Transitioning the nuclear industry to modern ways of working necessitates a comprehensive suite of modernization efforts, steered by industry-selected capabilities that epitomize a future-ready sector. This involves cultivating an environment that can attract a multi-skilled, talented workforce, essential for driving innovation and operational excellence. It requires the agility to adapt to evolving regulatory frameworks and fluctuating energy demand environments, ensuring resilience and sustainability. The industry must also be opportunistic in embracing new technologies, leveraging advancements to enhance efficiency, safety, and competitiveness. Furthermore, it is critical to establish transparent organizations and processes, fostering a culture of trust and accountability while enabling continuous analysis and improvement. These capabilities collectively form the cornerstone of a robust, modern nuclear industry that is prepared to meet the challenges and opportunities of the current and future energy landscape.

Previous work has shown that the process industry in general and nuclear to a high degree share basic organizational characteristics and functional areas. These commonalities can be used as a basis for assessing transferability of knowledge, tools, principles for organization, and staffing levels between nuclear organizations and the Norwegian continental shelf petroleum organizations (Thomas et al. 2020, Drøivoldsmo 2023). Therefore, we can use the lessons and principles employed by other industries to inform how nuclear can adopt ION as a successful paradigm. As shown in Figure 6, several functional areas between the two industries have a high degree of similarity.

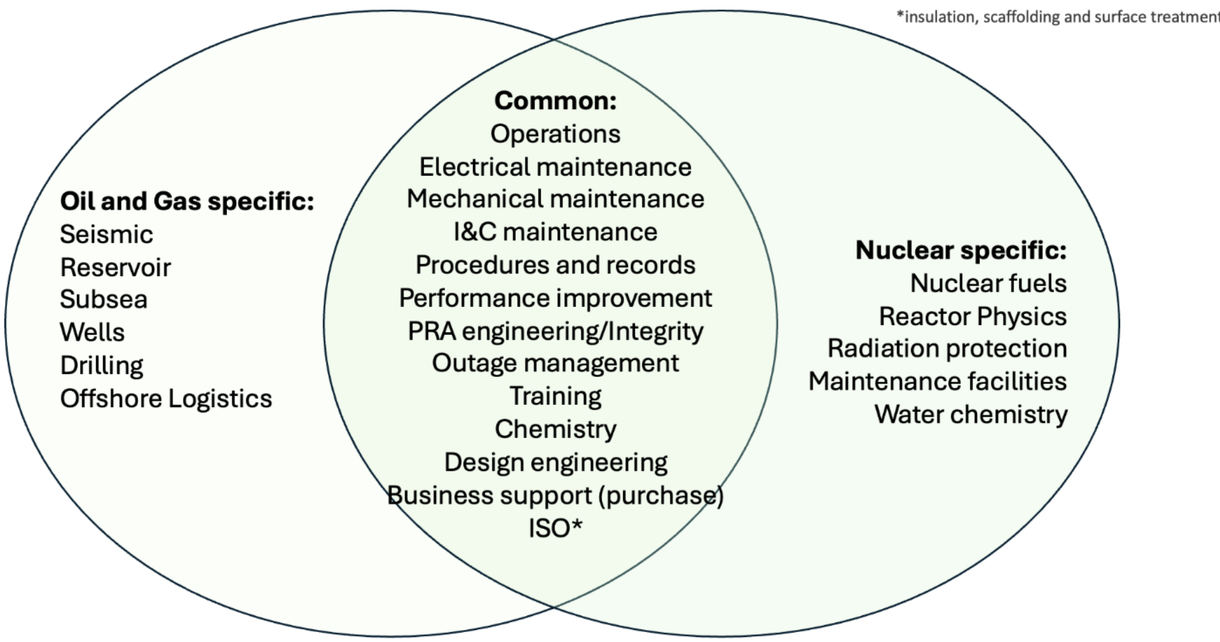

Figure 6. Functional area commonalties between nuclear and oil, based on Drøivoldsmo. (2023)

1.2.1 Oil and Gas Integrated Operations

The transition from standalone to integrated operations in the oil and gas industry has occurred over more than 20 years of evolution, driven by the need for greater efficiency, cost reduction, and sustainability (OLF 2005, Hepsø and Parmiggianini 2022). The drivers that generated momentum in O&G are the same drivers the nuclear industry is facing currently demonstrating yet another alignment between both industries.

The benefits include:

- Enhanced decision-making and work processes by transitioning operations to virtual onshore centers.
    - This addresses more manageable work locations for work-life balance
    - It also enables collaborative environments with multi-disciplinary teams across organizations
- Deploying IT solutions that facilitate remote, real-time management of operations, production facilities, maintenance, and logistics.

The basis for the transition has been:

- A unified digital infrastructure for production facilities
- Common standards for data transfer from distributed on-site operations to virtual centers
- Collaboration tools and updated work practices and competencies
- Industry expertise in supporting IO.

Based on insights from major oil companies and an evaluation of their take-up of integrated operations over time, this has been a stepwise process. However, when you look under the hood of this transformation, you still get a picture of two different phases (Figure 7). These two phases were partly overlapping in time and had no fixed end point. The first was more about taking organizational measures, while the second has been more about the use and creation of value from data. For the sake of readability of this report, we therefore make the generalization that IO in the oil and gas industry has been implemented through two major transitions: first, by integrating the company services across different locations, and second, by accelerating automation and analytics. Both transformations have changed work processes and the corresponding competence requirements profoundly.

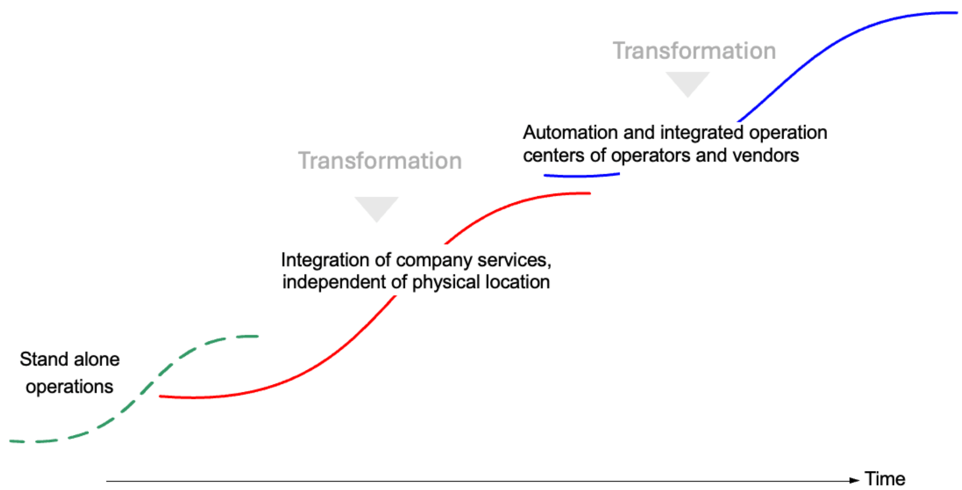

Figure 7. Major transitions in the development of IO seen in offshore oil.

1.2.2 From Standalone Operations to Integration of Onshore and Offshore Organizations (First Transition)

The traditional standalone operations approach had several deficiencies. Interaction between different oil-producing fields and resource sharing were limited. Data sharing was not fully automated, resulting in delays and inefficiencies. Most day-to-day decision-making was conducted on-site by offshore management, without involving the onshore organization. This led to a reactive rather than proactive central organization, which could not coordinate resources optimally across the larger organization. Onshore capabilities for real-time monitoring and control were limited. The lack of integration between fields and the implicit resource redundancy resulted in high operational costs.

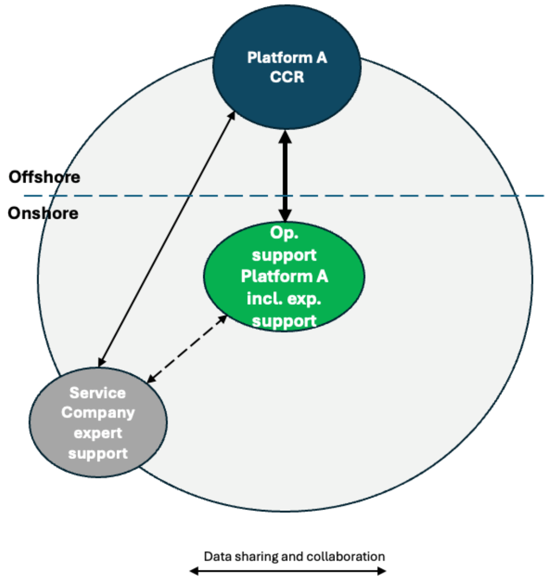

Figure 8. Principle sketch of standalone (traditional) operations.

As shown in Figure 8, for the traditional standalone operations era, the individual offshore platform had its own onshore operations support organization, with some sporadic limited support from onshore service contractor expertise. This model involved a large degree of offshore presence for both operator personnel and contractor personnel.

The traditional standalone model can be described by:

- Production units in the organization control their own resources
- Administration and planning are performed mostly offshore
- Some/sporadic operational support from onshore
- Limited expert support from outside asset operation support group
- Limited/no real-time data to shore
- Limited communication offshore/onshore (telephone, telefax).

To utilize the new opportunities in fiber optics and high-speed data transmission (Figure 9), it was necessary to make major changes in the operating model. The industry came together on this challenge. The first transformations with IO initiatives were implemented in parallel among the major operating companies with equivalent initiatives (Equinor, Shell, BP, Petrobras, and others). IO programs were developed and implemented in close collaboration with research institutions and the Norwegian regulatory authorities.

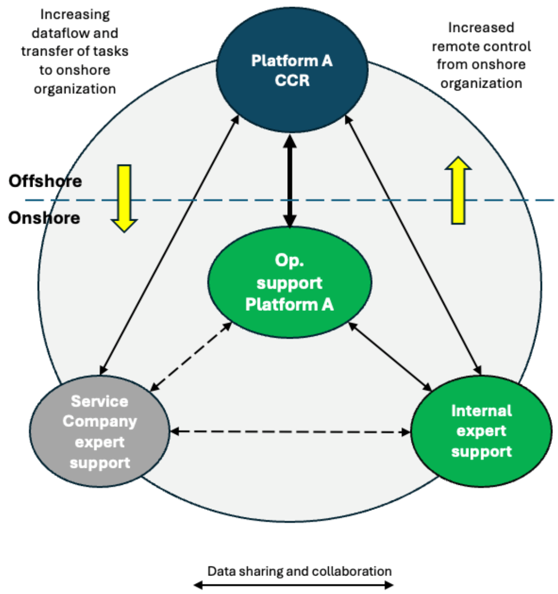

Figure 9. Principle sketch of integrated company services.

New characteristics connected with the integration of company services independent of physical location can be summarized as:

- Integrated onshore/offshore organization
- Continuous support from onshore operation support group
- High-capacity telephone and video communication offshore/onshore
- Administration and work planning performed mostly onshore
- Central control room and field operators integrated with onshore support
- Limited integration between operating and service companies and vendors
- Reactive expert support functions.

1.2.2.1 Addressing the First Transformation Challenges

Moving from standalone to integrated operations clearly showed that the challenges were not on the technical side. High-speed fiber optic networks and communication tools of a professional standard were in place early on and could be rolled out in the organizations. Piloting new operating concepts showed that with new data access and communication tools, many tasks that were previously assumed to have to be performed close to the production process could be performed equally well at central offices far from the plant. Despite this, the organization struggled to use the new opportunities effectively. Some examples are described in Thomas et al. (2020, pp. 70-71). An illustrating example is the first attempt to use body-mounted cameras. High-quality cameras were sent out to the oil platforms so that field technicians would be able to send live video streams of defective equipment to experts on land to get help with condition assessment and decisions about next steps. With very few exceptions, the cameras were not used. The reason the implementation failed was a lack of integration of the technology into onshore-offshore work processes before its introduction.

An important measure to remedy this type of problem was a strong investment in process-oriented management. Oil and gas companies have used work processes and workflow descriptions to create a robust system for retaining and leveraging knowledge, ensuring that valuable information is preserved and accessible for future use. A great effort was put into this area when it was realized early on that if IO was to be successful, the work process and work form had to be far more standardized than in the former standalone model. Using the modern approach, which integrates human actions into workflows, gave a strong framework for descriptions, requirements, roles, and responsibilities. If suppliers and contractors were to deliver services and work in the same way as the operating companies, it was not enough that the principles for the new way of working were understood internally. Business processes had to be standardized within each company, but also to a considerable extent across the industry to get vendors and contractors to work accordingly.

1.2.2.2 Leadership - Why Integrated Operations Is Different

IO stands out from traditional methods by bringing together diverse, geographically dispersed teams in a collaborative environment to achieve common goals. Unlike conventional structures, where team members often work in the same location and communicate face-to-face, IO relies on digital communication, bridging distances and disciplinary divides to enhance decision-making and operational efficiency. In the handbook for leadership in IO, Taylor et al. (2014) describe the principled and practical requirements IO managers face.

Distributed teams introduce several challenges. Communication often relies on digital tools and online meetings, which can impede personal connections and complicate clear, effective interaction. The diversity within IO teams, comprising members from various disciplines, backgrounds, and even different countries, adds another layer of complexity, making cultural and language alignment more difficult. Additionally, leaders frequently manage multiple teams with potentially conflicting goals, complicating efforts to unify vision and coordinate effort toward common objectives.

Leaders must navigate a complex environment where trust and effective delegation are crucial, often working with team members they have never met in person. Clearly defining roles, responsibilities, and authority boundaries is essential to ensure effective teamwork. Leaders must balance staying informed and removing obstacles with avoiding micromanagement in a setting where informal information channels like the coffeeshop are unavailable. Additionally, they need to adeptly manage conflicts by aligning local goals with overarching objectives, ensuring coherent progress toward common goals.

Leadership in IO is often shared, with different team members taking the lead based on the situation, utilizing their specific skills and traits. Effective IO leaders recognize when to step back and let others lead to address particular challenges. Overall, IO leaders must enhance their skills to overcome barriers and inspire their teams toward the collective IO vision of improved decision-making and safer, more efficient operations.

1.2.2.3 Elements That Require Competence Development – Collaboration Capabilities

Competence requirements for communication have evolved significantly with the introduction of IO. Competence is, in this report, used in a wide sense, describing both the professional competence required by a position in the organization, and the level of skills and understanding staff have for IO concepts. The modern approach to operations has redefined traditional notions of labor division and organizational interaction. This shift, discussed by Kaarstad et al. (2009) and Madsen et al. (2013), has led to new communication forms and team structures that transcend traditional boundaries. These changes emphasize the importance of social skills and attitudes in interpersonal interactions and digital communication. Today's competence landscape demands a blend of technical proficiency and adaptive skills, enabling employees to work effectively in diverse teams and across various functions.

Complementary teams, characterized by their diversity and varied skill sets, are more effective at solving complex problems than homogeneous teams. However, for straightforward tasks, homogeneous teams may complete the work more quickly. While complementary teams offer the advantage of diverse perspectives, they also present challenges due to members' differing backgrounds and interaction styles. The diversity within these teams provides a robust foundation for valuable interactions.

Effective communication within the group is crucial for leveraging the strengths of complementary teams. It serves as the essential glue of any organization. Various barriers can hinder efficient communication, including personal feelings, time pressures, non-verbal cues, information gaps, cultural differences, and selective perception. While communication is critical in typical settings, it becomes even more vital in an IO context. The complexity of IO, the involvement of multiple disciplines, and the diverse cultural backgrounds of team members necessitate exceptionally clear and precise communication.

Trust is a fundamental component in the introduction of new ways of working. Trust must be established down to the level that includes how work is performed in operations. The operations personnel who discover a problem must have confidence that the process for solving the problem is working. In the problem that is reported, all parties must have confidence in the reliability and integrity of the IT and communication systems on which the process is based. The information contained in the digital systems must be up-to-date and available to the user. Not least, there must be trust between the actors; for example, the operator must be able to trust that someone in a support center far away from the plant will deliver the necessary quality at the right time. Hepsø, Rindal, and Waldal (2013) summarize this as:

- Trust in each other's ability to perform work as intended
- Trust in the digital systems to mediate information as intended
- Trust in each other's ability to update information as intended.

This trust is developed by training on the operation model understanding and empowering staff with basic tools for daily collaboration in the distributed organization. Important elements described by Kaarstad, Rindahl, Torgersen, and Drøivoldsmo (2009) are team leadership, technology literacy and teams, roles and communication, and institutional language and culture. Traditionally, the role of a team leader has been to develop and mobilize team members' efforts. However, in a complementary work environment such as an IO organization, emphasis must be placed on the relationships between participants. In IO, tasks are often complex, and time to solve them is limited. Therefore, the success of complementary teams is crucial in an IO context. In this setting, the team leader's role is not merely to encourage individual contributions, but to ensure that team members understand and integrate each other's contributions into their interactions and teamwork. Team roles can be both formal and informal: some are determined by formal positions while others arise from personal traits or group dynamics.

In the context of IO collaboration and interactions, a long-standing question has been, "How can we optimize the use of our advanced collaboration rooms?" It now appears that organizations are increasingly asking, "What kind of work practices should our technology support and encourage?" (Rindahl et al., 2009). Technology literacy is not necessarily a matter of conscious competence or incompetence, and it is not controversial to state that digital natives—those born into an era of extensive digital tool use—have inherent advantages in high-tech collaboration environments. However, Rindahl et al. (2009) also note that individuals who have deliberately mastered these new technologies may have additional advantages, particularly in terms of sharing their skills effectively and using them strategically.

In many institutions, technical groups or teams develop a specific form of communication, often referred to as institutional or cultural language. In an IO organization, long-term collaborators may establish this type of language, including frequent use of abbreviations. When external parties are involved, there is a risk that this internal language will be incomprehensible. Therefore, it is crucial to recognize this internal jargon and to minimize its use when discussing with individuals who are not familiar with it or when the language used is not precise enough to avoid misunderstandings.

To prevent the use of internal institutional language in urgent or high-pressure situations, it is advisable to avoid such jargon and ensure clarity in all interactions. Additionally, for effective collaboration, it is essential to have a shared and deep understanding of the organization's core principles. For IO, it is necessary to clarify and adhere to the new division of work and operational guidelines. IO also requires a broader sense of responsibility among team members, so collaboration sessions should focus on fostering IO awareness. Since IO work processes are new, it is vital that everyone understands these processes and how technology is used to facilitate them. All stakeholders should be involved in establishing ground rules and expectations, and it is important to provide training and promote IO awareness.

1.2.3 Automation and Integrated Operation Centers for Vendor and Operator Companies (Second Transformation)

The second transformation has, to a much greater extent than the first, been centered around digitization initiatives. This has been a step-by-step process that started around the turn of the century with monitoring of heavy rotating equipment. In contrast to the integration of different parts of the companies, which required a major change to the operating model and comprehensive change management efforts across the entire organization, the development of functions to support condition-based maintenance has been able to proceed more stepwise.

New characteristics that describe the emergence of IO centers (Figure 10) can be described as:

- Real-time offshore-onshore collaboration and cooperation
- Establishment of a common holistic PTPG "One Team" mindset, including close collaboration between operating companies and service providers both offshore and onshore
- Establishment of operator and service provider expert support centers.

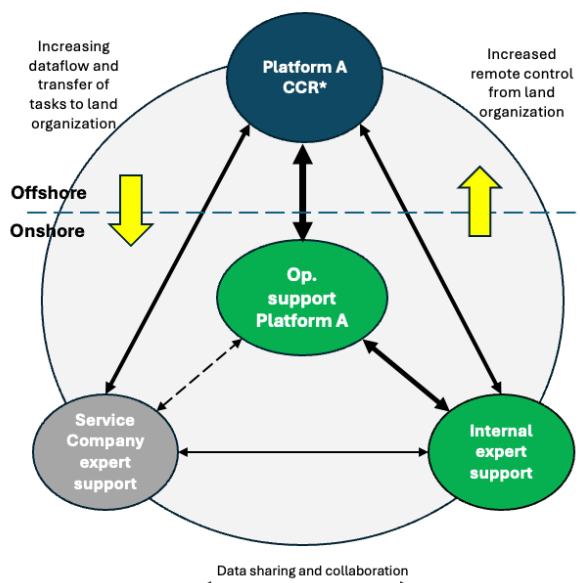

Figure 10. Starting use real-time data streams between onshore and offshore.

The competence requirements have become increasingly focused on optimizing remote equipment surveillance, where interpreting and diagnosing process anomalies and converting this information to a digital format is increasingly important. Input is obtained via sensor data, computed values, models, and simulations. Predictive and analytical capabilities initiated with IO require real-time data integration facilitated by advancements in information and communication technology (ICT) infrastructure. This allows for methods and models to be validated and enhanced with real-time data, enabling models and software to transcend their original boundaries.

During the second transition, there has been a significant increase in the competence needed to understand, utilize, and manage the data. Today, machine learning and artificial intelligence are further enhancing the predictive analytics of these models. Although models were already being integrated with real-time data and moved beyond local confines during the first transition, the current trend towards larger, centralized data centers allows for more efficient development of ICT tools, work processes, data governance, and competence building, scaling up operational and maintenance services. This shift aligns with a more centralized organizational model where support and competence centers deliver services to streamlined local assets. Enhanced ICT tools, upgrades and digitization of the I&C infrastructure and a more developed digital culture now enable better integration of work processes and data management within existing operational and maintenance workflows (Hepsø and Parmiggianini 2022). These technology improvements are aligned with the overall business strategy, particularly manning and cost reductions as prime drivers at asset and corporate levels.

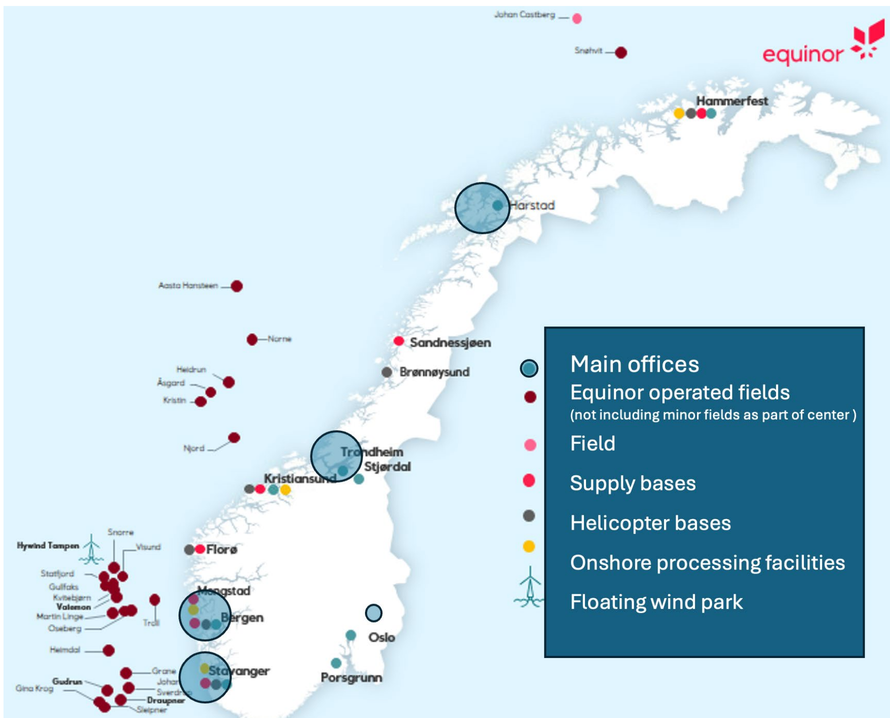

Figure 11. Virtual organization for control and support in Equinor.

Important technical contributions have come from the standardization of data exchange and recommendation of practices like the "Selection of system and security architectures for remote control, engineering, maintenance and monitoring" developed by the International Oil and Gas Producers Organization.

Looking at Equinor, the major operator in Norway, this has resulted in a model like the one shown in Figure 11. The figure shows an overview of Equinor North Sea operations, where the main offices support the larger organization, which consists of about 50 oil fields. The four main offices also have different responsibilities and expertise, with a meshed network of services to the offshore organization from the onshore offices. Vendors and contractor offices and services have been implemented in a similar way but are not shown in the figure.

1.2.3.1 ION Leadership Effects in Higher Levels of the Organization

The first IO transition was an industrial initiative, which was necessary to kickstart the change. The top management leader's role is not to advocate for IO, but they must promote a mindset that allows for IO. In the early stages of transformation, IO served as a hub around which change efforts could revolve, though the IO label has since been downplayed. Equinor managed to establish a commitment to IO up to the top levels of the company.

Senior leaders must understand that the interplay between people is essential for working across silos. It is important to think in terms of networks, not hierarchies. For this to work, each role must actively engage in every case and be willing to participate. Development cannot be left solely to the classical project model. Ownership must be built through information and collaboration with all participants.

1.3 Lessons from Shell Global Oil & Gas Operations

This report uses examples from Equinor to illustrate IO concepts and their development. It is important to emphasize that the entire industry has had similar experiences and has developed these concepts. De Best and Van den Berg (2012) summarize the elements identified by Royal Dutch Shell as necessary for a sustainable transition to an integrated operations way of working.

Alignment of Solutions with Business Needs: Solutions chosen for an asset must align with its business requirements. When these solutions are clearly tied to the asset's needs and understood by all relevant staff, they are more likely to be effectively utilized. Misalignment can occur if solutions are selected based on personal preferences for the asset or of functional leaders rather than business needs. This can lead to underuse, with staff opting to bypass solutions due to time and resource constraints. Consequently, implemented solutions can become obsolete, with data and models growing outdated, diminishing their usefulness.

Skills and Training for Relevant Staff and Supervisors: Staff need comprehensive training that encompasses awareness, business understanding, process execution, and technical skills. This includes business training (understanding objectives), process training (specific activities), and technical training (using the tools). Continuous coaching by experts helps embed these processes within the asset teams and operations staff. Post-implementation, refresher training and onboarding training for new employees are essential.

Comprehensive Support for Solutions: Support should cover all aspects: business, process, technical, IT, and data. Each asset follows a specific support model based on a corporate template, combining local support with regional support structures and third-party assistance.

Ownership and Sponsorship Post-Implementation: A dedicated business owner, sometimes from both the asset and functional groups, should be designated to provide guidance. Regular reviews against key objectives ensure focus on achieving business benefits and allow for corrective actions as needed.

Regular Process Review by Process Owners: Process owners must regularly review the execution of processes, ensuring they operate as designed and making improvements or corrective actions when necessary. This is part of a process-oriented operations model.

Maintenance of Field Instruments and Infrastructure: With IO solutions, asset functionality depends heavily on the quality of real-time data. Maintenance practices, both in the field and in the office, must reflect the need for high-quality data.

Clear Accountabilities for Data Quality: The effectiveness of IO solutions relies on data quality. Given that these solutions integrate various types of data across disciplines, ideally one entity should be accountable for real-time data quality, from instruments to the real-time data historian. This entity should manage repair and enhancement actions, coordinating with instrument engineers, telecoms, IT, etc.

1.4 Implications for the Nuclear Industry

In essence, for the nuclear industry to continue successful operations in an ever-evolving landscape, it must learn to foster an innovative environment, which can be realized through the implementation of the ION journey. The ION approach is a tested and proven pathway that leads the industry towards a modern way of working, based on the learnings from IO in the oil and gas industry. This journey emphasizes the significance of organizational structure as a foundation for fostering innovation, which in turn has been demonstrated to reduce operational costs and increase flexibility. By realigning organizational practices, encouraging creative thinking, and embracing technological advancements, the nuclear industry can successfully transform itself to meet current and future challenges.

The transition to IO in the oil and gas industry has been underway for over 20 years, offering valuable lessons for the nuclear industry. By leveraging these insights, the nuclear sector can potentially simplify operations, reduce operational costs, and address organizational and human challenges more effectively. The key technological driver of IO is advanced communication technology, including real-time data integration and monitoring, which enhances decision-making and operational efficiency. However, the most crucial lessons learned are in developing and implementing new work methodologies. Challenges often arise when integrating technology into individual work processes, underscoring the need to ensure its intended and effective use.

Changing the way of working in larger parts of an industry requires a unified understanding of the principles of how work should be carried out. At the organizational level, this is very much about establishing mechanisms for promoting interdisciplinary collaboration to enhance problem-solving and innovation and fostering a culture of continuous improvement and knowledge sharing.

2. ADDRESSING CHALLENGES IN IMPLEMENTATION

Implementing ION in plants will help boost innovation, leading to greater efficiency, transparent operations, and alignment with organizational objectives. ION's primary benefit is a reduction in the cost of operations, but the strategy involved will help transform the industry into pro-active problem solvers capable of independently overcoming challenges and adapting to changes in the economy and technology. With ION, plants are better prepared to not only address current issues, but also anticipate and manage future ones, securing their ongoing success. Additionally, ION adoption in the nuclear industry enhances employee contributions and fosters modern, innovative work environments. It enables the use of new skills and technologies for problem-solving, involves staff in diverse teams, and includes them in decision-making processes, promoting transparency and organizational coherence.

With cost efficiency as the high-level driver, the innovations in oil and gas have come about as a result of the industry setting ambitious targets for transforming the industry from standalone to integrated operations. The enabler has been long-term strategic thinking for infrastructure that allows for future use of data and effective collaboration within and between companies. This has enabled an innovation model with a think big–act small approach, where joint development and a shared understanding of objectives have set the direction for growth. By establishing a unified understanding of an IO operating model and supporting principles, it has been possible to facilitate smaller, incremental innovations within organizational units. The first transformation (ref chapter 1.2.2):

- Prepared and made first steps with data, communications, and understanding of new operational model
- Reallocated functions according to the IO concept and changed work processes accordingly, all the way out to the sharp end of operations

- Developed a concept with guiding principles to lead the smaller steps (innovations).

Key features of this innovation model include a top-down approach that establishes the strategic framework for the roles and collaboration of all actors—operators, vendors, suppliers, and contractors—within the entire ecosystem. The second transformation (ref chapter 1.2.3) focuses on maturing the organization through continuous testing and experimentation with smaller innovations. This phase emphasizes harnessing data and automation opportunities, scaling innovations across the organization, and further developing collaboration tools. It aims to deepen the understanding of organizational structure and information flow while empowering and realizing small-scale innovations within the organization. To work systematically with change, it is important to have tools, in the sense of implementation methodology, which, in Equinor's experience has been a central issue to ensure systematic gap analysis of complex IO cases and efficient IO implementation based on the IO core capability stack.

2.1 Think Big–Act Small

A useful framework for managing and describing incremental development is the capability approach. While key requirements must align with high-level goals and deliverables, detailed requirements should be tailored to the organization's needs for people competence, technology, work processes, and governance integration into operations (PTPG). Developing organizational capabilities like collaboration and analytics is a stepwise process. Each step involves practical testing and learning, revealing new opportunities not evident in earlier stages.

Establishing an innovative culture is crucial for leveraging these opportunities to create new business processes across disciplines and company boundaries. It is therefore important to be able to define the resource requirements for the capability an organization needs for its own innovation (a generic example of this is attached in Appendix A to this report).

2.1.1 People, Technology, Process, and Governance Approach

As described by Henderson et al. (2012), the concept of capability arose to manage the complexity inherent in modern organizations. Kogut and Kulatilaka (2001) define capability as the integration of processes, technology, and governance. Henderson and Kulatilaka (2008) extend this definition to encompass governance mechanisms and human-centered aspects such as culture and values (Henderson et al. 2012). Thus, a capability can be described as a cohesive set of interconnected activities involving people, technology, processes, and governance that directly contribute to economic value creation. This definition emphasizes two key points. First, the value of a capability is determined by its impact on business outcomes, always evaluated from the perspective of the end customer. This ensures that the logic of capability development flows from external market needs inward, rather than being driven solely by internal considerations. Second, a capability represents a synthesis of people, technology, processes, and governance, with each component being equally essential. While technological advancements might be more straightforward to implement than cultural shifts, both are indispensable for achieving success. This holistic perspective is crucial, because the value derived from capabilities arises from their synergistic combination rather than from any single component in isolation.

A success criterion for capabilities design is scalability. The key is developing capability resources that ensure both efficient operation and scalable growth. Scalability can mean scaling from one unit to multiple units in the organization, or scaling as part of a platform approach, where capabilities are developed as modules that can be reused by other parties in the industry. Partners can then use these modules to add value to the system, and independent companies can create complementary value through collaboration.

The challenge most often lies in implementing the new capabilities. PTPG aims to ensure that all actors and elements necessary for a successful implementation are in place. Henderson et al. (2012)

introduces a stack model that outlines competencies to enhance capability development. This model logically categorizes technology and skill levels, facilitating effective communication within the organization. The importance of designing the stack model in a way that makes it work in each local case for application cannot be underestimated). In addition to generic stack models developed for the company, local premises in different parts of the organization will have to be assessed in sufficient detail and conformed to reach assumed quality (Lilleng and Sagatun 2010, Lilleng et al. 2012). Lessons learned from the capability implementation include ensuring a high-quality central company IO model for capabilities, and integrating local experience into the design, both to benefit from local competence and tacit knowledge and to improve the quality of the local routines (expose deficits in the local performance). However, the detail of this model goes beyond the level of discussion in this report.

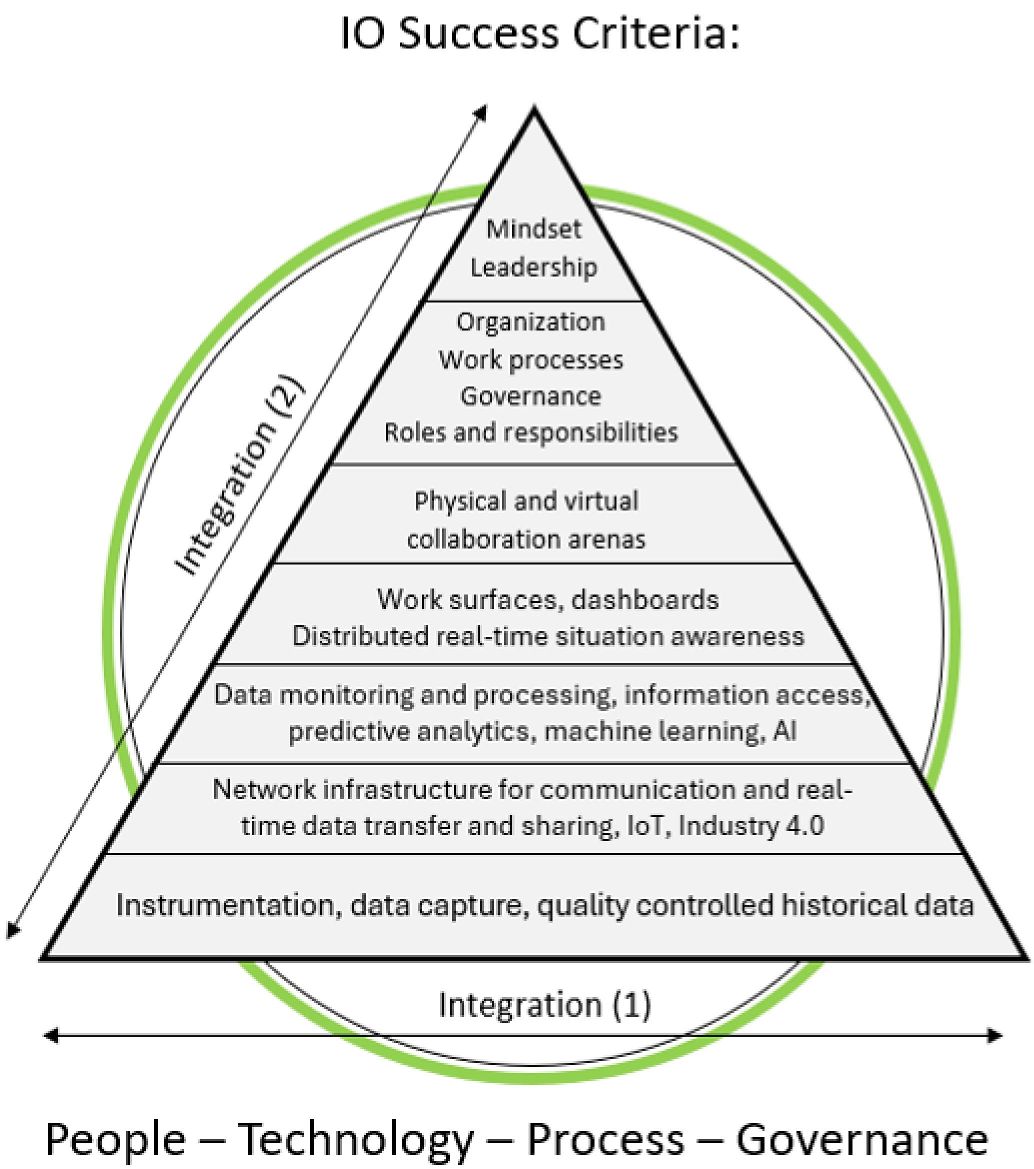

Figure 12: IO drivers and success criteria. All criteria need to be described and checked for each case and organizational unit to ensure that all criteria are met. This requires both horizontal (1) and vertical (2) integration and analysis for each target capability. (from Lilleng et al. 2012)

2.1.2 People

People and resources: What skills, competencies, and behaviors are required to execute the process and utilize the supporting technologies? People are, of course, at the heart of value creation for most organizations. The concept of core competencies highlights the immense value found in the culture, knowledge, and creativity of individuals.

2.1.3 Technology

Technology: What technologies and working environments are necessary to enhance capability? Technology enhances value by enabling people to connect and work together in new and more efficient ways. The IO concept has been developed based on a continuous advancement in data transfer networks, evolving from low-bandwidth communication for offshore operations to high-speed fiber-optic networks capable of handling real-time data. This also incorporates new sensor technologies that significantly enhance the informational value derived from shared data. Seeing these technologies from a capability approach, the network foundation encompasses not only hardware and software but also the human, process, and governance components essential for sustained and effective data sharing. With this setup, individuals in different locations or working for different companies can access and manipulate the same data simultaneously.

2.1.4 Process

Process: What are the core value processes and underlying processes that need improvement and updating? IO will by nature increase the complexity of processes, needing different disciplines to contribute to various parts of a process. Traditionally working within each discipline, processes are essential to overcome the challenge with interdisciplinary collaboration. Process is not just internally oriented, but also relates to external partners (e.g. vendors). In a company with a highly market-oriented business model, consequently, various parts of the organization have large interfaces with vendors they rely on.

2.1.5 Governance

Governance and organization: What organizational structures, incentives, and relationships are essential to execute the capability effectively? Governance provides the framework and discipline necessary to effectively develop and sustain capabilities. It establishes the rules, processes, and relationships that enable the organization to be compliant with regulatory and company-specific demands and must be part of all stages of capability development. Governance frameworks also include mechanisms for risk management and mitigation, and effective governance helps in identifying, assessing, and managing these risks appropriately in the early stages of designing a capability. An organization's ability to apply governance on the local level is important for IO. Such an application demands that governing elements like roles, responsibilities, and risk information are present and understood in day-to-day performance of work.

2.1.6 Organizational and cultural outcomes from PTPG approach

The transition from traditional standalone operations to integrated operations in the oil and gas industry had a profound cultural impact on how companies managed resources and shared information. Integrated operations emerged through collaboration with industry players, research institutions, and regulatory authorities. This shift was not just a technological upgrade to fiber optics and high-speed data transmission, but a cultural transformation that redefined the relationship between offshore platforms and onshore support. IO initiatives led to continuous onshore support, centralized control rooms, and better communication technologies, fostering a more proactive and cohesive organizational culture.

Leadership in IO required adapting to a culture of shared responsibilities and digital communication to more appropriately manage teams that were geographically dispersed and composed of diverse members. This necessitated developing trust in digital systems, and in the expertise of individuals who might be located far from the operational site. The cultural shift extended to collaboration capabilities, where competence development focused on communication and teamwork across disciplines and locations, thereby breaking down the traditional hierarchical structure of an organization in favor of a networked approach.

Overall, the cultural impact of moving from standalone to integrated operations was significant, requiring a shift in mindset from isolated operations to a networked approach, emphasizing collaboration, standardization, and trust in both people and technology.

2.2 ION Approach, Innovation, and Industry

An organizational culture that focuses on more networked approaches and trusting the value contributed by each employee can be characterized by several key attributes that collectively foster creativity, efficiency, and a forward-thinking mindset:

- Open communication: establishing channels for free and transparent communication encourages the sharing of ideas and knowledge, which is crucial for sparking innovation.
- Workplace satisfaction: a positive work environment that supports work-life balance, recognizes achievement, and values employee contributions leads to higher engagement and motivation to innovate.
- Empowered and informed decision-makers: equipping employees with the necessary information and authority enables them to make decisions that can lead to breakthroughs and improvements.
- Collaboration: encouraging teamwork across departments and disciplines can lead to a cross-pollination of ideas, fostering a culture where innovation can flourish.
- Clearly defined metrics and goals for success: setting clear, measurable targets provides direction for innovation efforts and a way to track progress and celebrate achievements.
- Leadership modeling desired behaviors: leaders must exemplify the behaviors they wish to see throughout the organization, such as taking calculated risks, encouraging experimentation, and learning from failure.
- Increased exposure to cases and challenges for employees supports accelerated career development and greater expertise in areas of interest.

When these characteristics are actively cultivated and integrated into the fabric of an organization, they create an innovative environment where continuous improvement is the norm and where employees are inspired to develop and implement new ideas that can transform the industry. These characteristics are also found in the principles of IO. Some are directly addressed, while others are met implicitly by the new way of working that emerges as part of the transformation to an IO paradigm.

2.2.1 Principles for the IO Journey at the Industrial Level in Collaboration Between Companies

A clear explication of capabilities and operational principles to guide transformation/future innovation in North Sea O&G industry initiative was agreed upon during the years leading up to the first transformation. The manning models developed for North Sea operations were largely based on robust offshore/onshore ICT infrastructure and extensively digitized I&C systems, which allowed for remote operation and control solutions as well as profoundly changing the maintenance strategies to include condition based and predictive maintenance capabilities. These are key to reduced onsite manning levels and operating cost reductions. For the first transition, goals and principles for reducing offshore manning and improving speed and quality of decisions were key to extracting value from the work. Analyses were carried out on a large scale across the entire organization with the purpose of identifying the potential for reallocation of work. Simple rules and principles had to be developed for guiding organizational analysis in a clear and consistent way.

Typically, high-level principles like “Central onshore organization focus on surveillance, support and supervision. Offshore plant focus on execution and safety” and “Move all administration/planning and other possible work tasks from the plant to the main office/vendor office” were formulated to set the direction. One of the most used principles in detailed analysis work was "Work shall be done at the location where it can be done the most effective way, and by the best possible utilization of competence." Competence requirements are the driving force behind the placement of functions in the organization and must be delineated down to who is responsible for carrying out the individual work task.

A significant advancement in the same timeframe was the full adoption of process-oriented management. Companies implemented process-oriented management at all levels, from managing work processes and governing documentation to digitalizing and automating processes. This created a unique framework for moving away from local work practices to describe and standardize a new joint operating model, and at the same time educate the larger organization in the new way of working. Examples of principles used are:

- Active use of standardized work processes with continuous adaptation to new IO technology
- Cooperation across professions and organizations through work processes supporting cooperation arenas prepared a high level of concurrent work execution.

A clear focus was also placed on building an organization across former silos. “Eliminate organizational, geographical, discipline, and cross-company barriers by sharing relevant information in real time and collaborating.”

For all operational principles and at every level of analysis, any change in roles and responsibilities must maintain or enhance safety. The focus of safety efforts should be on improving risk understanding among all involved parties and proactively addressing the safety aspects of work.

Applying a functional, task-oriented focus (bottom-up), and simultaneously working with guidance (top-down) made it possible to clarify what the new operating model entailed in terms of task execution as direct input to training programs. One of the most profound results of this approach was the more advanced way of building the manning model. With a common operation model and a high-quality data set with time estimates not only for maintenance hours but for the entire organization, plant manning could be done according to minimum requirements and activity level.

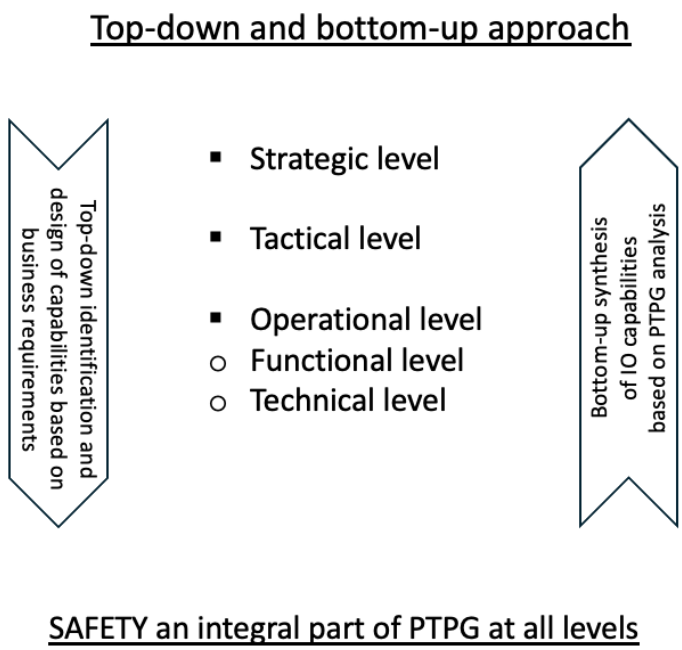

Figure 13. Diagram illustrating that all levels of an organization must be involved in solution analysis and implementation.

Additional principles actively used for function reallocation were:

- Better utilization of scarce resources by establishing support and expert centers. Vendors work from their own facilities.
- Move from manual to data-driven way of working. Share relevant real-time data and collaborate.

3. DELIVERING ION TO INDUSTRY

To realize the concept of ION, the nuclear industry must undertake a strategic approach to create a workplace that is both modern and conducive to innovation. This approach includes the following steps:

1. Engage nuclear industry leadership:
    a. Educate industry leaders on the benefits of ION and how it can significantly improve business operations, safety, and competitiveness.
    b. Advocate for the adoption of ION principles at the executive level to ensure commitment and resource allocation for modernization efforts.
    c. Begin shifting the mindset in nuclear to better approach long-term strategic modernization.
2. Develop transformation targets:
    a. Identify and establish Key Performance Indicators (KPIs) that extend beyond traditional nuclear industry metrics.
    b. These KPIs should embody principles that drive necessary innovation and should be clearly communicated across all levels of the industry to ensure alignment and understanding.
    c. Determine the methodology for measuring these KPIs, ensuring that they are quantifiable, relevant, and capable of tracking progress towards the desired innovative state.

3. Collaborate with industry on technology deployment:
    a. Partner with industry stakeholders to deploy new technologies in a manner that aligns with the outlined transformation targets.
    b. Ensure that the integration of technological solutions is strategic, with a clear understanding of how these technologies contribute to the overall capability requirements of the industry (PTPG).
    c. Facilitate a continuous feedback loop between technology implementation and transformation target outcomes to track effectiveness and guide further innovation initiatives.

Through this process, the nuclear industry can begin adopting ION and becoming more innovative, more capable of managing their assets and resources, and more likely to attract a skilled workforce that can propel the industry forward.

Knowledge retention is also addressed in these strategies through advanced training techniques, by integrating training and reference materials into work processes, and through collaborative work environments that extend beyond the organization and include service providers and interdisciplinary teams. Clear communication, trust in the process, and transparency in the organization foster an environment that employees can clearly navigate to identify, analyze, and solve problems in a modern way that meets the company's objectives. Most of all, knowledge retention begins to occur through retention of skilled employees that seek out the modern and innovative environment that the ION journey helps create.

3.1 Engaging Industry and Support Organizations

Addressing leadership and increasing understanding in the nuclear community is paramount to the success of implementing ION. Leadership is already aware of the challenge in workforce attraction and retention. They are also exploring ideas to retain the tacit knowledge of those retiring from the workforce. However, using ION as an "inside-the-fence" solution requires shifting the mindset of the nuclear industry to embrace a new model of risk-informed innovation and encouraging leadership to begin embodying the behavior, culture, and principles behind ION. With the aim of incepting the ideas of ION into the nuclear ethos, many efforts to explain ION, discuss successful examples, and bring together leaders in the industry were undertaken.

The LWRS program hosted a webinar discussing the lessons learned from IO in the oil and gas industry and how the nuclear industry can follow a similar path towards achieving long-term sustainability and modernizing how work is performed. The webinar was designed for research and development managers, plant operators, regulatory affairs specialists, and other professionals involved in the nuclear energy sector who are committed to driving innovation and operational excellence.

The webinar presentations focused on the concept of ION, drawing lessons from 20 years of experience in the North Sea oil and gas sector. Following a brief overview of the current state of ION, there were four main sections in the webinar. The sections outlined the potential benefits of adopting an IO approach to improve safety, efficiency, and operational effectiveness within the nuclear industry, through presentations titled:

- "The Common Challenges in U.S. Nuclear and Norwegian Oil and Gas" – Focusing on the commonalities within functions, technology, and organization
- "Value Capture During 20 Years of Integrated Operations Within O&G" – Operational cost, production efficiency, and safety
- "Step by Step Development of the Integrated Operations Model" – The IO concept applied in transforming operations, maintenance, and modifications.

- "Methodology for Continued Development of Integrated Operations for Nuclear" – Combining small steps and long-term goals for transition into ION.

After the presentations, the webinar shifted to an open-forum format, allowing participants and presenters to discuss opportunities in nuclear transformation, sustainability, and attracting new talent.

3.2 Key Points from the Webinar

1. U.S. nuclear and offshore oil and gas have a high number of common challenges. This first topic presentation identified the similarities in challenges faced by the U.S. nuclear industry and the Norwegian oil and gas sector, particularly in terms of safety, technology, and organizational structure. The presentation further highlighted the evolution of safety practices in the Norwegian oil and gas industry, driven by significant incidents that led to a shift from prescriptive regulation to a risk-based integrated safety management approach.
2. Oil and gas has seen extensive value capture from integrated operations. The second presentation emphasized this, including examples of reduced operational costs, enhanced production efficiency, and improved safety.
3. The step-by-step development of the IO model and its application in transforming operations, maintenance, and modifications were shown using the capability approach to integrated operations, with a focus on the IO journey that involves eliminating barriers (organizational, geographical, and disciplinary) through real-time information sharing and collaboration, developing capabilities (People, Technology, Process, Governance) at all levels, and shifting from manual to data-driven operations.
4. The following four IO implementation steps were presented: (1) Transition from standalone operations to integrated operations, focusing on aligning strategies across industries. (2) Sharing resources between plants for safer and more efficient operations. (3) Expanding automation and integrating operations across the company, including vendor partnerships and remote operations. (4) Extending the use of AI, digital systems, and remote control for further optimization and safety.

The last presentation focused on methodology for IO implementation. The presentation concluded with a possible methodology for integrating operations into the nuclear sector, stressing the importance of safety at all levels and phases. It also outlined successful strategies (e.g., combining case and model analysis) and less successful approaches (e.g., self-assessment workshops), offering lessons learned for transitioning to ION. The full slide pack from the webinar and a summary of the questions and answers can be found in appendix B and C, respectively.

Representatives participated in two International Atomic Energy Agency (IAEA) workshops, where they delivered presentations on the role of innovative technical solutions in enhancing performance and reducing costs at operating nuclear power plants. These presentations highlighted the significant findings and impacts of fostering an innovative culture and showcased in-progress and implemented ION business case solutions.

Additionally, efforts to explore research collaboration on the sustainability of nuclear power plants were initiated through the Canadian/UK/US "Exploring Research Collaboration on Sustainability of Nuclear Power Plants," hosted at Idaho National Laboratory, leading to the beginning of knowledge sharing with Canadian Reactor Sustainability Programs. This collaboration has not only facilitated international engagement but offers the opportunity to integrate nuclear industry cultures from different countries and leverage programs akin to LWRS to share lessons learned and benefit from each other's efforts and opportunities.

Furthermore, involvement with the NEI workforce engagement working group has been directed towards developing a strategic plan for workforce pipeline development, where ION's perspective could be instrumental in aligning "inside-the-fence" operations with "outside-the-fence" communications, advertisement, and pipeline development. Possible collaborations have been discussed to synchronize training and pipeline development for individuals entering the workforce, as well as to ensure alignment with ongoing training. These actions are geared towards promoting "inside-the-fence" solutions and engaging industry representatives in a meaningful dialogue about workforce development.

Lastly, representatives attended the American Nuclear Society's Utility Working Conference, which devoted a large portion of their sessions to workforce development. These discussions focused on human resource solutions to workforce attraction (i.e. compensation, benefits, remote work, etc.) for inside-the-fence solutions. Other suggestions echoed the efforts of the NEI workforce engagement group to develop talent pipelines and market nuclear jobs. However, these efforts will not address the workforce competition expected from the construction of advanced reactors and newer reactor builds. Shifting the culture within plants and innovating how work is performed will be needed to increase legacy nuclear's attraction to the next-gen workforce. It was quipped that presenting new hires with an enormous three-ring binder containing all their work processes was indeed a poor way to retain new employees; there was agreement that modern technology must be a focus for improving workforce attraction. Following this discussion was a question regarding who within the nuclear industry's ecosystem must lead the effort to modernize nuclear energy. Following a long pause, the panel answered that nuclear utilities and their leadership must take the lead in this effort. While these occurrences are anecdotal and not officially documented, it left an impression on the author that there is still much work to do in engaging nuclear leadership to embrace the idea that, for nuclear to continue being successful, there must be a strategy in place to begin serious and long-term modernization efforts.

3.3 Developing Transformation Targets and Technology Deployment

The integration of initial "transformation targets" into the LWRS plant modernization efforts represents a strategic inflection point for the nuclear energy industry. As we move forward, it is essential to actively incorporate knowledge retention strategies, efficient resource management, process review, and improvement, as well as the establishment of high-level principles to set the course for long-term objectives. LWRS can support, advise, and collaborate with industry, but nuclear utilities must take the lead in developing, supporting, and owning their transformation targets. The development of industry-wide checklists that reflect set targets and goals will provide a clear roadmap for achieving these aims.

PTPG analysis of all proposed solutions is critical for understanding the potential impact of implementation and ensuring that these solutions are scalable. This will enable us to identify the most effective technologies and process improvements to adapt them across the industry. Moreover, follow-up measures are necessary to quantify the value added by the implementation activities to industry operations, ensuring that the benefits are tangible and contribute to the overall advancement of nuclear technology and safety.

The NEI report underscores the demographic challenges facing our workforce, with a significant age gap between near-retirement and early-career employees. The observed attrition among early-career employees due to factors such as work-life balance, advancement opportunities, and cultural fit is concerning. To address this, creating a modern and innovative work environment that meets the expectations of the next generation is imperative. This includes leveraging I&C advancements and nurturing a culture that affords collaboration, trust in the innovation process, and transparency as to how and why processes are in place.

Competition from new advanced nuclear plants further necessitates the adoption of innovative strategies to retain and attract talent. Knowledge retention is pivotal; the loss of tacit knowledge threatens to erode our expertise, efficiency, innovation, and decision-making capabilities. Modernizing the workplace through technology, optimizing processes, and embracing data-driven decision-making can make the industry more appealing to the next generation.

The transition to an ION business model presents an opportunity to centralize resources, enable remote operations, and enhance collaboration. Upskilling the workforce to align with the digitally-focused and innovative education available today is also essential. Trust-building and the communication of clear goals are fundamental for cultivating an innovative culture within our organizations.

Organizational structures that support mentorship and technologies that facilitate advanced training techniques and accessible information at the point of work are key to effective knowledge retention strategies. Aligning efforts "inside the fence" with those "outside the fence" is vital for building trust with new recruits and bridging the skill gap left by retiring legacy workers. Digital communications and remote meetings require innovative strategies for knowledge capture and cultural integration. Lastly, team structures that promote collaboration and align local goals with organizational objectives will drive the industry towards a sustainable and innovative future.

In conclusion, the nuclear energy industry must embrace a holistic approach that incorporates future-oriented strategies, innovative technologies, and a workforce culture that is attractive to both current and future generations. By doing so, we can ensure the continued safe, efficient, and sustainable operation of nuclear facilities while paving the way for the integration of advanced nuclear technologies.

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APPENDIX A

APPENDIX A

Example: PTPG Maturation of an Innovation Capability

The Carnegie Mellon People Capability Maturity Model (P-CMM) is a framework designed to improve workforce practices, aligning them with organizational goals to enhance performance and capability maturity. Inspired by this framework, Reegård, Drøivoldsmo, and Farbrot (2020) developed a generic PTPG – maturation matrix with requirements for innovation and continuous improvement.

INNOVATION maturation matrix	People	Technology	Process	Governance / organization
Higher P-CMM levels: Integrating innovation into daily work	☐ Self-motivated to initiate innovation ☐ Continuously uses new knowledge and technology ☐ Provides ongoing feedback within the organization	☐ Adapts and improves tool portfolio	☐ Identifies and implements new tools, phases out outdated ones ☐ Ensures long-term competence in intrapreneurship ☐ Improves and establishes new processes	☐ Leadership supports and involves in innovation ☐ Promotes diversity and "creative slack" ☐ Uses networks for knowledge exchange
Intermediate P-CMM levels: Standardizes practices for innovation and orientation towards development	☐ Knowledge of inter-unit relationships and innovation tools ☐ Practices continuous improvement	☐ Mentors colleagues in innovation tools ☐ Facilitates cross-unit projects	☐ Continuously evaluates and adjusts innovation processes ☐ Focus on suitable team composition	☐ Leadership articulates innovation purposes ☐ Established communication and coordination arenas ☐ Uses prioritization of initiatives
Lower P-CMM levels: Manages and Controls Innovation in the individual unit as needed	☐ Knowledge of unit deliverables and key individuals ☐ Initiates and joins changes	☐ Facilitates innovation processes ☐ Shares relevant information within and across units	☐ Ensures access to innovation and collaboration tools ☐ Maintains an innovation initiatives overview	☐ Leadership sets innovation direction ☐ Ensures capacity for innovation participation ☐ Provides feedback and requests results

APPENDIX B

APPENDIX B

Slide-pack from webinar

ION – Integrated Operations in
the Nuclear Industry

How the Nuclear Industry
can benefit from 20 years of North Sea Oil and Gas
experience by transforming the way we work through
an Integrated Operations approach.

The Common Challenges in US Nuclear and Norwegian Oil and Gas

Session 1:

Focusing on the
commonalities within functions, technology and
organization

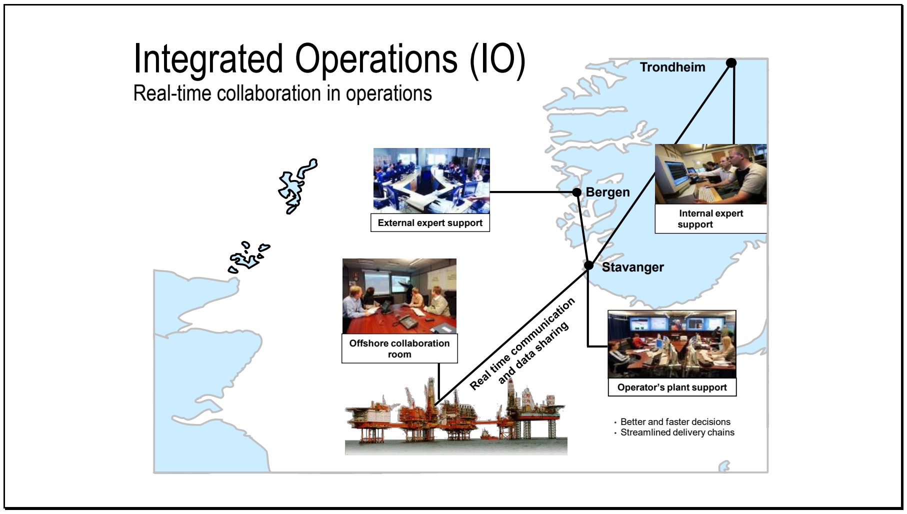
Nuclear – Offshore Petroleum Commonalities

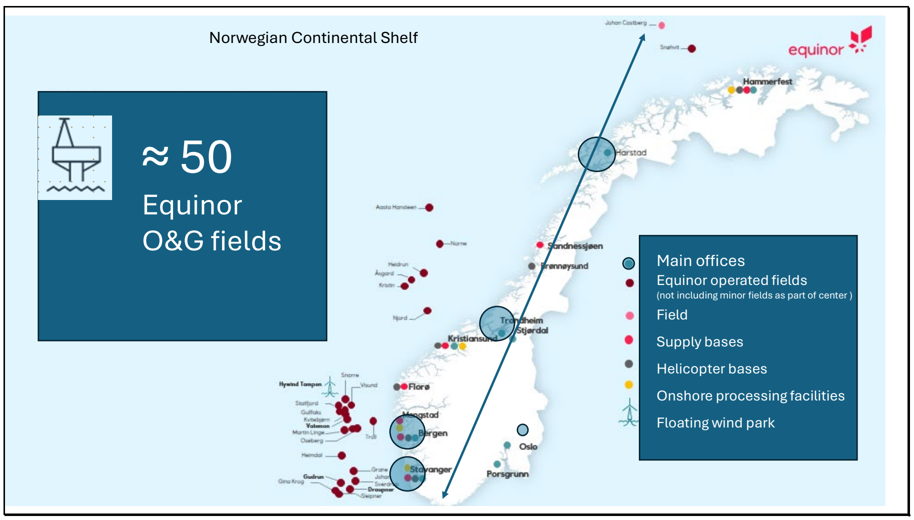
Nuclear

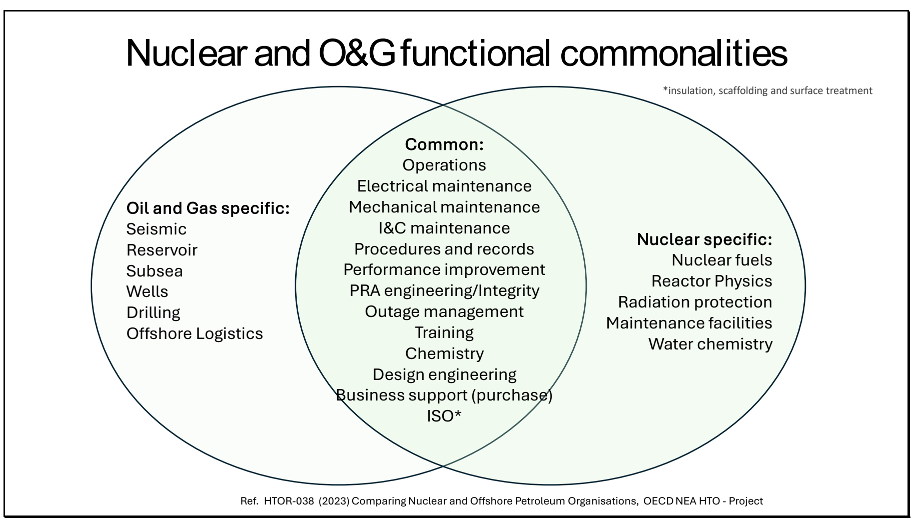
- High environmental consequence of failure
- High organizational complexity
- High technical complexity
- Strong regulatory regime
- Interest in license renewal > 80%

Offshore Oil & Gas

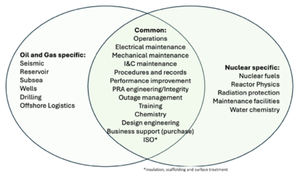
- High environmental consequence of failure
- Higher organizational complexity
- High technical complexity
- Strong regulatory regime (risk – based)
- Most fields with substantial life extension


Integrated Operations (IO)
Real-time collaboration in operations
Trondheim
Bergen
Stavanger
External expert support
Internal expert support
Offshore collaboration room
Operator's plant support
Real time communication and data sharing
· Better and faster decisions
· Streamlined delivery chains

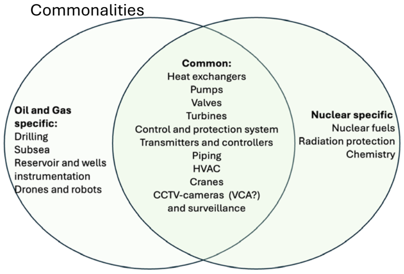

Norwegian Continental Shelf
equinor
≈ 50
Equinor
O&G fields
Hammerfest
Harstad
Sandnessjøen
Brønnøysund
Trondheim
Stjørdal
Kristiansund
Florø
Mongstad
Bergen
Stavanger
Oslo
Porsgrunn
Main offices
Equinor operated fields
(not including minor fields as part of center)
Field
Supply bases
Helicopter bases
Onshore processing facilities
Floating wind park


Nuclear and O&G functional commonalities
*insulation, scaffolding and surface treatment
Oil and Gas specific:
Seismic
Reservoir
Subsea
Wells
Drilling
Offshore Logistics
Common:
Operations
Electrical maintenance
Mechanical maintenance
I&C maintenance
Procedures and records
Performance improvement
PRA engineering/Integrity
Outage management
Training
Chemistry
Design engineering
Business support (purchase)
ISO*
Nuclear specific:
Nuclear fuels
Reactor Physics
Radiation protection
Maintenance facilities
Water chemistry
Ref. HTOR-038 (2023) Comparing Nuclear and Offshore Petroleum Organisations, OECD NEA HTO - Project

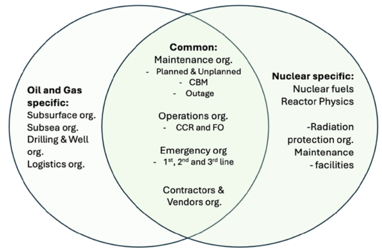
Nuclear and O&G Functional Commonalities



Nuclear and O&G Equipment and Technology Commonalities



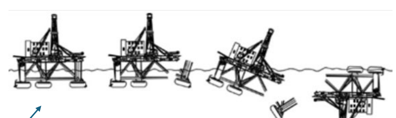
Nuclear and O&G Organisational Commonalities



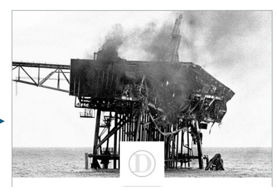
Ref. . HTOR-038 (2023) Comparing Nuclear and Offshore Petroleum Organisations, OECD NEA HTO - Projects

Safety focus and regulatory development in Norwegian Oil and Gas

- Early Development (1960s-1980s)
  - Safety regime inherited from US onshore production, with undesirable safety practices and blowout accidents
- Major Incidents and Regulatory Response (1980s-1990s)
  - Collapse of the Alexander L. Kielland platform (1980, 123 fatalities). Significant safety reforms, including the adoption of stricter structural integrity standards and enhanced emergency preparedness.
  - UK sector, (1988, 167 fatalities) Piper Alpha disaster. Leading to Norway adopting more rigorous safety management practices.



Process of capsize of Alexander L. Kielland



Norwegian ocean industry authority

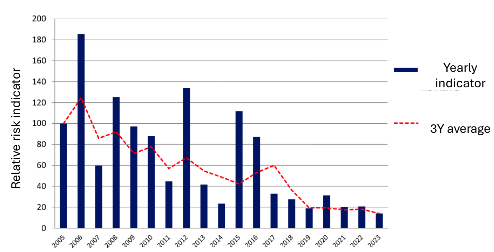
Moving from prescriptive regulation to risk-based and internal control

Comprehensive Safety Framework (1990s-2000s)

- **Petroleum Safety Authority** Norway
- **Risk-based safety approach**
- **Integrated safety management**

Continuous Improvement and Modern Practices (2000s-Present)

- **Technological Advancements**
- **Barriers Management**
- **Human Factors and Safety Culture**



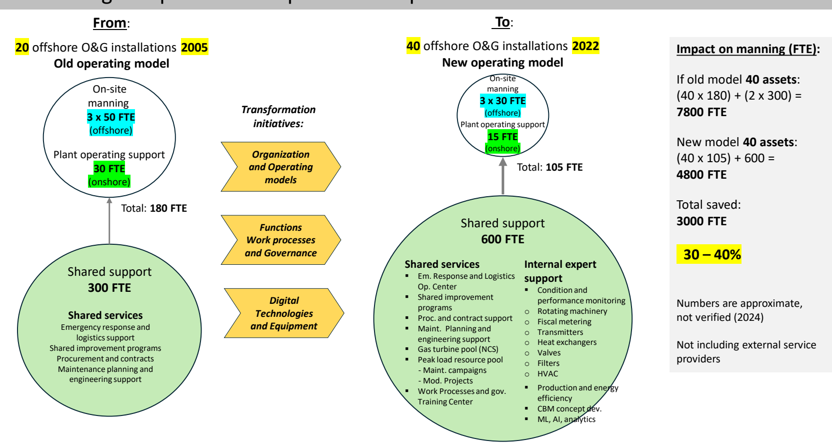
Total indicator, major accidents, production facilities, normalized against working hours

Regulatory and Industry Collaboration through Tripartite Collaboration: Norway uses a collaborative approach involving government regulators, industry, and labor unions to develop and enforce safety standards

Value capture from 20 years of Integrated Operations within O&G

Session 2:
Operational cost,
production efficiency and safety

Restructuring of Equinor`s O&G production operations* NCS



* Not including drilling-, subsea- and maritime operations

Initiatives for transformation - guided by the IO concept

High level
Target Capabilities

Goal: New operational paradigm through new ways of working

Organization and Operating models

- Common standardized lean operating model (2009)
- Extended internal shared services
- **Expert Support Centers** and centralized real-time plant monitoring
- Shared Integrated Service Contracts. Number of contracts drastically reduced
- Further development of remote operations and unmanned operations concepts

Functions Work processes and Governance

- Common work processes for operations, maintenance, logistics, project developments and other
- Governance through work processes requirements, roles and responsibilities
- Standardized meeting schedules and collaboration arenas
- **Maintenance efficiency programs**, including campaign and condition- based maintenance, CBM

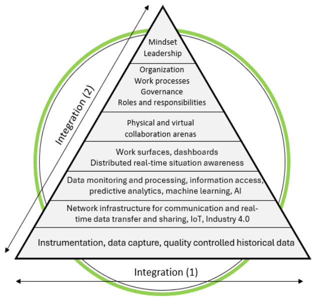
Digital Technologies and Equipment

- High capacity offshore/onshore communication infrastructure in place 2005
- **Extensive instrumentation** for New Field Developments
- Mature Fields modification projects, including major I&C (SAS) upgrades
- **Broad implementation of digital technologies** incl. collaboration and data sharing technologies, digital twins, drones, robotics, automation, CCTV, process simulations, digital field worker and other
- Strategic development programs for data-driven smart operations incl. Industry 4.0, IoT, additive manufacturing, deep analytics, machine learning and artificial intelligence

The Integrated Operations (IO) initiatives in Equinor were implemented in parallel with other operator`s equivalent initiatives (Shell, BP, Petrobras and others), the **Norwegian Oil Industry IO Program (2003-2008)**, and in close collaboration with research institutions in Norway including IFE, the IO Center initiative at the University of Trondheim and with Norwegian regulatory authorities

Equionor`s IO Core Capability Stack Model (PTPG)

IO Success Criteria:



People – Technology – Process – Governance

Equinor`s Core Capability Stack Model consists of seven **IO Success Criteria** representing the required criteria that need to be in place for effective implementation and **value capture** from integrated operations

Equinor`s IO Concept is based on the **PTPG** (People Technology Process Governance) mindset initially defined by IFE as the **MTO** (Man Technology Organization) safety concept

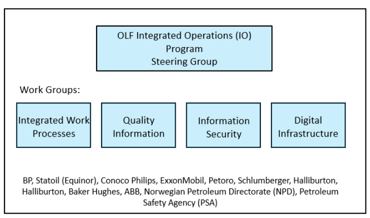
The IO Success Criteria pertain to all operational areas analyzed by Equinor in the development of integrated operations

Equinor developed an ***IO guiding questionnaires*** library and ***IO Step Model*** to support efficient assessment and implementation of integrated operations

Equinor`s Integrated Operations Methodology and Value Proposition concept was first published in 2010 (SPE 128576)

Equinor IO Assessment methodology: **Horizontal**/lateral integration (1) + **Vertical/**deep integration (2) for each Target Capability (IO goal)

Norwegian Oil Industry (OLF) IO Program 2003 - 2008



OLF IO Program established based on White Paper:
"***e-Operations – the 3.rd efficiency leap on Norwegian Continental Shelf***"
(2003)

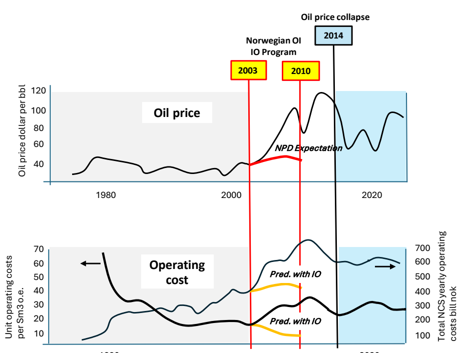
Integrated operations (IO):

*"New operating models and data driven collaborative ways of working based on a holistic **MTO perspective** characterized by remote control, increased number of tasks performed onshore and reduced offshore manning, proactive use of real time data streams, and extensive use of digital technologies and tools offshore and onshore"*

Published reports:

- **Integrated Work Processes**
- **Value Potential for IO NCS**
- Digital Infrastructure Offshore
- Quality Information Strategy for NCS
- Information Security Strategy and Guidelines

Operating cost development 2003 - 2022



Norwegian Oil Industry expectations 2003 – 2010

- ***Continued depressed oil price*** *and falling production*
- ***Increasing operating costs***

Prediction with IO 2003 - 2010

- ***Increase*** *in total operating costs restrained*
- ***Significant reduction*** *in operating costs per Sm3 o.e.*

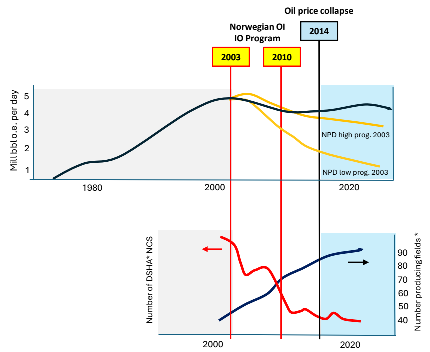
Actual development 2003 - 2014

- ***Oil price increase*** *from 50-60 to > 100 USD per barrel*
- ***Significant increasing operating costs -> 2012***
- ***Declining operating costs 2012 - 2014***

Actual development 2014 - 2022

- ***Oil price collapse 2014***
- ***Stabilized operating costs 2014 ->***

Production and **safety** development 2003 - 2022



* DSHA: Defined Situations of Hazard and Accidents (excluding helicopter)

Norwegian Petroleum Dir. expectations 2003 - 2025

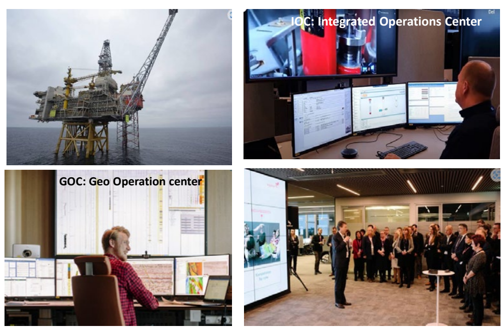
- ***Falling long term production trend***
- ***Declining investments**, few new field developments*

Actual development 2003 - 2022

- ***Stable high production level***
- ***Number of fields on production increased** from approx. 40 to > 90. Average production per field reduced by approx. 50%*
- ***Significant improvements in safety/HSE***

* Average investments per year NCS 2010 – 2020 approx. 180 bill nok (approx. 18 bill US dollar). Number of subsea production systems increased from 310 in 2003 =310 to approx. 450 in 2022

Expert Centers in Equinor – opening 2018



"This is a completely new way of working and represents one of the biggest changes we have made in the petroleum technology and geology during the last 20 years.

This will help form our digital future where tasks are carried out and experience gained and shared in smart ways"

Ketil Hove
Head of Operations Equinor

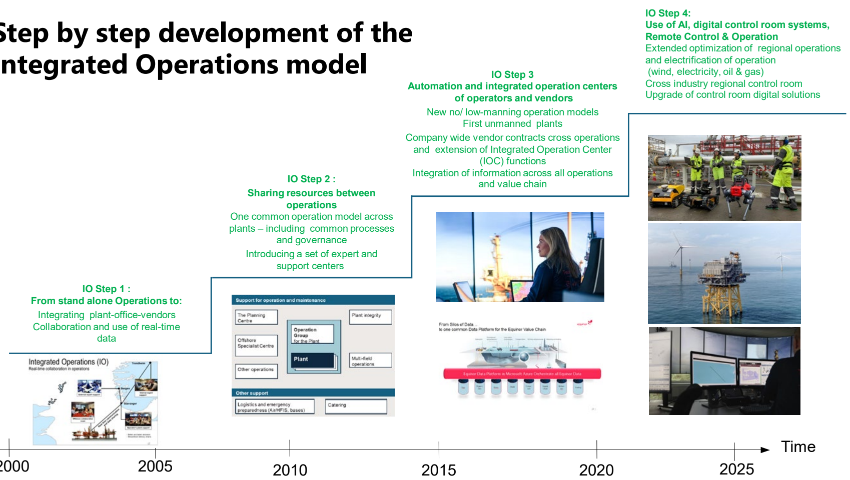
Step by step development of the Integrated Operations model

Session 3
The IO concept applied in transforming operations, maintenance and modifications.

Principles for the IO journey at the industrial level in collaboration between companies 2003

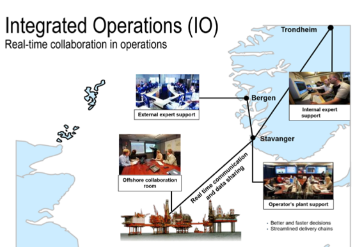
- Eliminate organizational, geographical, discipline and cross company barriers by use of sharing relevant information real time and collaboration
- PTPG (People, Technology, Process, Governance) capability development, at the Strategic, Tactical and Operational level
- Better utilization of scarce resources in support and expert centers. Vendors work from their own centers
- Move from manual to data driven way of working. Share relevant real-time data and collaborate
- Move all administration/planning and other possible work tasks from the plant to the main office/vendor office

Step by step development of the Integrated Operations model



IO Step 1 :From Standalone operations to IO

IO Step 1 :
From Stand alone Operations to:
Integrating plant-office-vendors
Collaboration and use of real-time data



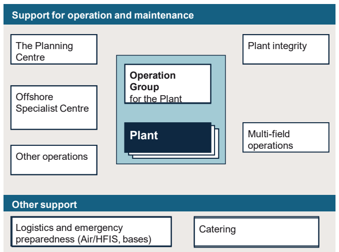
Focus:

- Common cross industry focus. Each company adopted the concept aligned with each company strategies and plans
- The Integrated Operation concept is the integration of People, Technology, Processes, and Governance (PTPG) enabled by information and communication technology to make better and safer decisions faster to optimize operation and production
- Across industry level, company level, operation level and discipline level
- Provide the right group of people with the right information at the right time to make better decisions and execute tasks

Before	IO metodology
Serial workprocesses	Synchronized
Single discipline	Multidiscipline teams
Dependent of physical location	Independent of location
Decisions based on experience data	Decisions based on Real-time Data
Reactive	Proactive

IO Step 2 : Sharing resources beteen plants

IO Step 2 :
Sharing resources between operations
One common operation model across plants – including common processes and governance
Introducing a set of expert and support centers



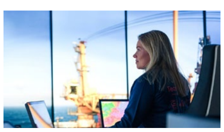
Focus and Goals:

- Safe, efficient and predictable operation
- One way to run your business
- Integrated organization with high competence

Message from the CEO in Equinor:
"For Equinor this is about achieving safer and better operations through more uniform operating methods and continuous learning across operating units.
The changes make it possible to use the company's collective resources in an even better way, and new opportunities are created for the individual to utilize and develop their expertise"

IO Step 3 : Automation and extended integrated operation model

IO Step 3
Automation and integrated operation centers of operators and vendors
New no/ low-manning operation models
First unmanned plants
Company wide vendor contracts cross operations and extension of Integrated Operation Center (IOC) functions
Integration of information across all operations and value chain

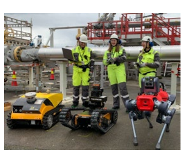


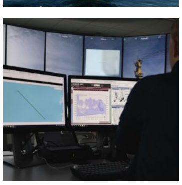
Focus: Continue the capability development using the integrated operation concept.

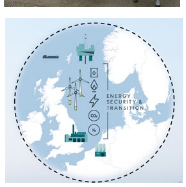
- More integration with company wide agreements with vendors and closer integration of capacity and expertise
- Operation model for new not permanent manned operations Startup of the first not permanent manned plant
- One common integrated data solution linking the complete value chain and all plants and operations.
- Extension of the Integrated Operation Center (IOC) to integrate vendors, optimize availability and use of data across the company.

Equinor CEO:
"The establishment of the IOC contributes strongly to our ambition of being a global digital leader. It will enable us to optimize production and better predict support needs, ensuring optimally efficient and safe operations from our operated fields. The center may also improve sharing of knowledge in our organization and further improve our collaboration with our suppliers and partners"

IO Step 4 : Extended use of AI, digital control room systems, Remote Control and Operation







Focus: Continue the capability development using the integrated operation concept.

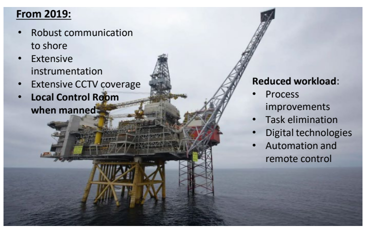
- Use of AI for optimization and support
- Use of robots and drones for operation
- Upgrade of control room digital systems for remote operation
- Multi industry – regional control room for wind, electricity and Oil&Gas
- Continues development of vendor integration and collaboration from the Integrated Operation Center to optimize operation and best utilization of skills and technologies
- Electrification of the Oil&Gas plants leading to constrains in the operation because of power limits in the grid

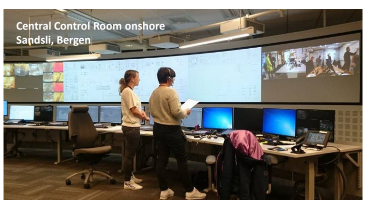
Equinor Capital Marked update 2024:
"Industry leading carbon efficiency and execution capabilities"

Integrated Operations case history Oil & Gas, NCS

– operations, maintenance and modifications

Valemon Operating Model - staged manning reductions





<u>2015</u>: <u>**Production start-up (1)**</u>

- Manned **365** days per year (1)
- 365 x 17 = **6205 FTE days per year**
- <u>Central Control Room offshore</u>

<u>2017</u>: **4/2 manning model (2)**

- Manned **244** days per year (4 weeks manned, 2 weeks unmanned)
- 244 x 17 = **4148 FTE days per year**
- <u>Central Control Room offshore</u>

<u>2019</u>: **2/4 manning model (3)**

- Manned **122** days per year (2 weeks manned, 4 weeks unmanned)
- 122 x 17 = **2074 FTE days per year**
- <u>Central Control Room onshore</u>
- LCR offshore when manned

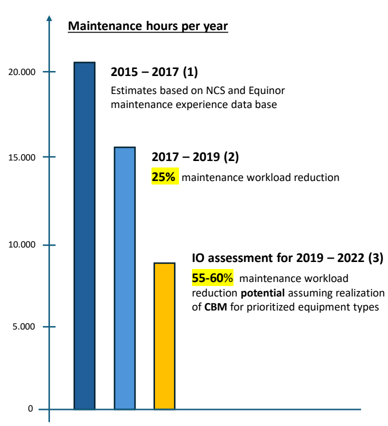
<u>IO (PTPG) assessment</u>:

Minimum Manning Potential based on IO concept incl. further reduction of maintenance workload

- *2 x 2-week campaigns (40 Personnel On Board)*
- *9 x 2 days to cover all operating requirements (13 POB)*
- *(28 x 40) + (18 x 13) =* ***1354 FTE days per year***

Total reduction potential: ***6205 – 1354 = 4851 FTE (78%)***

Valemon Field – staged maintenance workload reduction



<u>**IO (PTPG) assessment (3) maintenance workload Velemon Field:**</u>

- Analysis of all preventive and corrective maintenance activities/concepts
- Identification of potentials for stretching of preventive maintenance intervals and reducing number of activities per maintenance concept/package
- Actions for elimination of unplanned corrective maintenance
- Identification of maintenance workload reduction potentials through **CBM** for selected equipment

<u>**Condition Based Maintenance (CBM):**</u>

- Using all condition data including manual inspection and function testing data and on-line condition data from instrumented equipment
- Remote condition and performance monitoring (RC&PM) expert support from centralized **Integrated Operations Center** (IOC) – and external parties
- The **CBM concept** requires **a new mindset** challenging governance requirements, standards, categorization of security critical equipment (SCE), preventive maintenance concepts (PM program) and statistical analysis for safety (SIL,PFD, SRS)

*** SIL**: Safety Integrity Level, **PDF**: Probability of failure on demand, **SRS**: Safety Requirement Specifications

Instrumented equipment ready for RC&PM and CBM

CBM Capability for:

Heavy rotating machinery
- Gas Turbines/Compressors
- Export pumps
- Fire water pumps

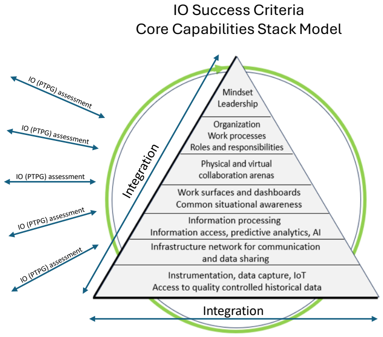
Valves
- Pressure Safety Valves
- Emergency Shut Down Valves

Filters
- Membrane oil/water filters
- Gas turbine inlet/air filters

Safety Critical Transmitters
- Pressure transmitter
- Temperature transmitters
- Process/flow transmitters

Heat Exchangers
- Shell and Tube heat exchangers

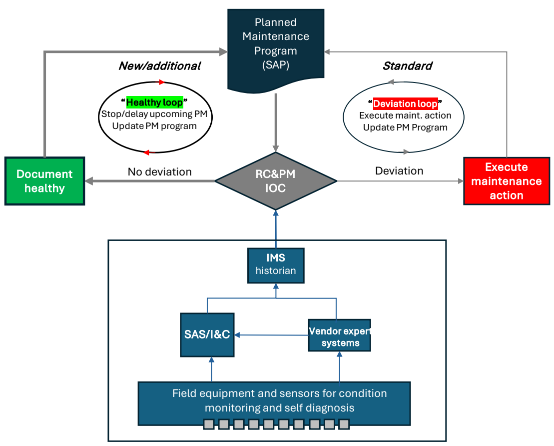
HVAC systems
- System approach incl. fans, fire dampers a.o.



People – Technology – Process - Governance

* RC&PM: Remote Condition and Performance Monitoring. CBM: Condition based maintenance

Condition Based Maintenance (CBM) Concept – exploiting the "healthy" data

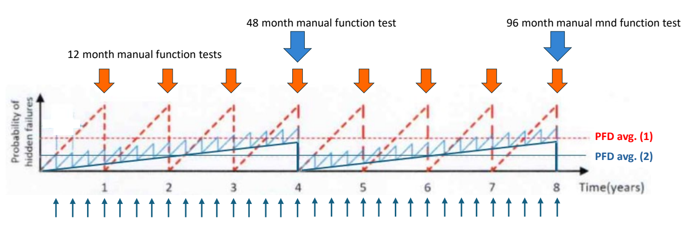


Condition Based Maintenance (CBM):

- On-line continuous data monitoring a requirement
- Diagnostic coverage documentation for all defined equipment and function dangerous fault modes based on representative statistics and type/extent of instrumentation
  = ***challenge!***
- Automated/semi-automated documentation of "healthy" according to safety integrity level (SIL) for equipment and function
  = ***challenge!***
- Stopping all unrequired manual inspections and function testing by automated/semi-automated "stop/delay" function in SAP (ERP) calibrated with Control Room alarm values
  = ***challenge!***
- ***Healthy/no deviation documentation*** *represent a "negative" dataset with a huge potential for maintenance efficiency and safety improvement*
- *HEALTHY LOOP IS NOT SATISFACTORILY COVERED IN TODAYS GOVERNING DOCUMENTS AND REGULATORY REQUIREMENTS*

Value of documentation of "healthy" in CBM

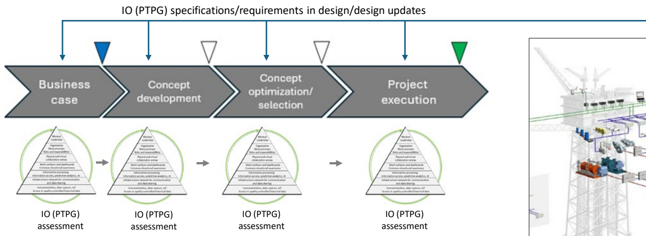
Case: Time series data from safety pressure transmitters

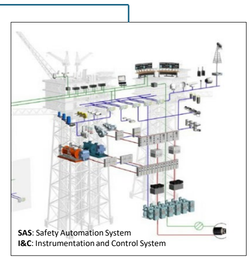


Value: 3 months automated/semi-automated "health checks" combined with **48 months** manual functions tests reduce probability of failure on demand (PFD) with ca. **50%** (doubling safety/SIL), and reduce function test maintenance costs with **75%** compared to fixed interval **12 months** manual function testing

Use of the IO Concept in project developments

Field development projects, Modification projects, Technology development projects, Improvement projects, Contract development projects *and other*



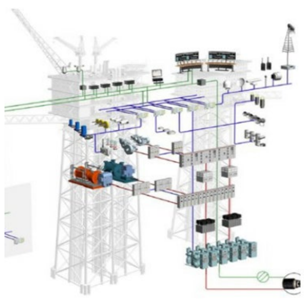


The **IO Concept** has been applied in a series of North Sea projects during the last 10-15 years, including major **SAS/I&C** modification projects/upgrades. ***Target Capability****: SAS/I&C system allowing remote, efficient and safe operations, modifications and control.*

Issues that should be repeatedly assessed through the execution of SAS/I&C modifications/upgrading projects:

People: *Leadership and competence requirements for administration of new infrastructure, contractor involvement;* ***Technology:*** *Instrumentations (analog, digital), data formats, servers, data routing, interfaces, cyber security, segregation;* ***Process:*** *Condition monitoring and remote control of all topology components, service agreements, 3.rd party access;* ***Governance:*** *Ensuring compliance with internal and regulatory (updated/recently changed) requirements*

Integrated Operations in SAS/I&C modification and upgrading projects



Key learnings: *Mindset*

1. "Soft" **IO Capability design requirements,** - ref. collaboration capabilities, end-to-end data streams, efficient and safe access solutions, procurement cost vs. reliability evaluation procedures, cyber security verifications, training programs etc. **must be assessed and accepted** by project management **from onset of the project**

2. **Large rest scopes** at handover to the operating organization for which it is poorly prepared to handle **must be avoided**

"Installation" of instrumentation and hardware does not ensure integrated operations capabilities!

Methodology for continued development of Integrated Operations for Nuclear

Session 4:

Combining small steps and long-term goals for transition into ION

Development of methodology

Long term R&D in direct combination with industry needs

- Direct applied deliveries towards implementation of IO concepts in the industry
- Government founded projects with universities, research institutes, operators and vendors

Example methods for analysis and implementation

Successful:

- Combining case and model - PTPG
- Revised Function reallocation approach
- Strategic principles and targeted guiding questionnaires

Less successful:

- Improvement workshops
- Self-assessment of IO compliance
- Generalized models for monetary value assessment

Guiding Principals for the IO journey at the Industrial Level

Top-down and bottom-up approach

Top-down identification and design of capabilities based on business requirements

- Strategic level
- Tactical level
- Operational level
  - Functional level
  - Technical level

Bottom-up synthesis of IO capabilities based on PTPG analysis

SAFETY an integral part of PTPG at all levels

Answering the need for guided function re-allocation

ISO 6385
Work systems

Control centers rooms

- ISO 11064 - 1
- IEC 60964
- NUREG 0711
- EPRI 1008122.
- IEEE Guide HFE Application
- NORSOK

Entire organization

IO Function reallocation - method

IO visions, strategies and verifiable goals

Detailed verifiable goals and requirements (safety, technical and economical)

According to strategies, develop solutions by means ends analysis

Task identification and analysis of functions

(including PTPG solutions) and work processes

Third party evaluation of consequences

Verification against performance criteria and org. constraints

Verification against internal company agreements

Verification against governing documentation

Decision about implementation

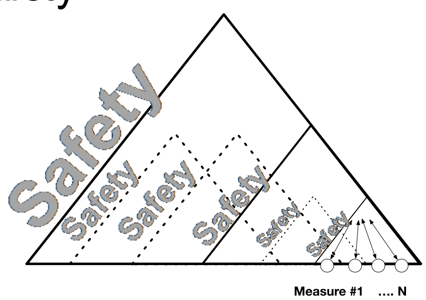
equinor bp ConocoPhillips

Principles for the IO journey at the industrial level in collaboration between companies 2003

- Eliminate organizational, geographical, discipline and cross company barriers by use of sharing relevant information real time and collaboration
- PTPG (People, Technology, Process, Governance) capability development, at the Strategic, Tactical and Operational level
- Better utilization of scarce resources in support and expert centers. Vendors work from their own centers
- Move from manual to data driven way of working. Share relevant real-time data and collaborate
- Move all administration/planning and other possible work tasks from the plant to the main office/vendor office

IO PTPG analysis - Safety

- **Any IO capability shall have a safety goal connected to it**
- Safety shall be a red thread through the analysis
- Safety shall be focused on all levels of the analysis



Time spent on task - minutes	Task description	Competence requirments	Phyiscal location	Participants	Safety aspects	Limitations for moving task	Safety Consecquence	Solutions PTPG	New allocation
120	Coordinate plans from the different disciplines and units, and facilitate regular planning meetings	Qualified operations planner	Office	All executive discipline leaders, managers onshore ops.	None	None	Unchanged	Pe: Collaboration training T: Video conference, visualization	Planner Main office
15	Discipline leaders handover to night-shift	Knowleged of the production facilities	Office	Discipline leaders day and night shift	All parties have knowlegde of ongoing and planned work	Onshore opening hours	Unchanged	Pr: Collaboration training T: Video conference, visualization	Planner Main office
30	Coffe meeting 9 am. Status information gathering from executive personell	Gather information,	Coffeeshop	All executive disciplines	Status and information gathering	Personal contact with crew	Risk for reduced information quality	T: Prepare for virual participation Pr: Reallocate to discipline responsible,	Planner main office + new local responsible

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PTPG Function reallocation method

Higher level business requirements and agreed goals for analysis

Function analysis with the purpose of hypothesis testing

Categorisation and reallocation of work tasks according to principles

Organisational and work process role modeling

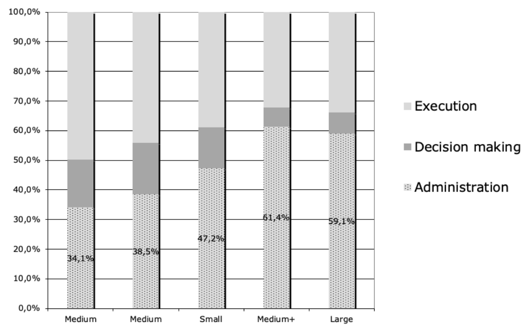
f#	Job title	Current allocation	Time	Activity	Description of activity	Location	Partici-pants	HSE aspects	Preconditions	Constraints for reallocation	HSE implications	Solutions for human / organization	Solutions for technology	General improve-ments	Role	Preliminary allocation	HSE criticality	Overlap ping tasks

- The analysis is aimed at detection of constraints
  - Based on an overview of functions and task performed a field, all functions are analysed against a hypothetical future scenario.
  - For example: "Are there any limitations for doing this task from the main office's premises? *What are the constraints for this task if it should be performed by another staff position"*
  - If constraints are identified, they are analysed further

Slide 40

Work task time categorization

Amount of time spent on different categories of work for leaders, foremen and staff positions on different size offshore assets

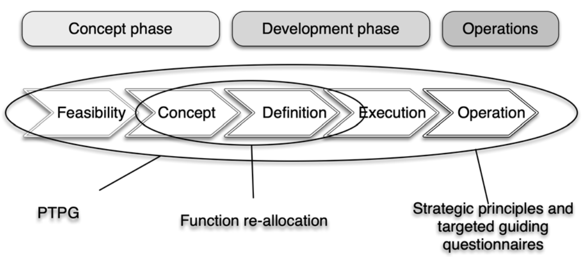


Summary IO methodology

Methods must be able to deliver all levels in the organization (strategic, tactical and operational levels)

Methods must cover all the PTPG elements

Methods must deliver to all phases in small and larger projects



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APPENDIX C

APPENDIX C

Q&A from webinar

Regarding the IO Core Capability Stack Model pyramid, can you elaborate on the top tier relative to leadership mindset changes that were needed to make this model successful?

The combination of senior leaders allowing room for innovation while setting a direction is crucial. Top leaders must be able to motivate throughout the organization. It's essential that some at the top have credibility, which must "be earned."

A key point is the mindset of those skeptical of change. To build this mindset, leaders must engage these individuals to work purposefully within each case. The concept and PTPG triangle are not the focal points. Roles and responsibilities are not confined to a single layer in the pyramid; it is crucial that responsibility is assumed at each level.

Senior leaders must understand that the interplay between people is essential for working across silos. It's important to think in terms of networks, not hierarchies. For this to work, each role must actively engage in every case and be willing to participate. Development cannot be left solely to the classical project model. Ownership must be built through information and collaboration with all participants.

IO was initially a corporate initiative, which was necessary to kickstart the change. Top management leaders don't need to advocate for IO, but they must promote a mindset that allows for IO. In the early stages of transformation, IO served as a hub around which change efforts could revolve, though the IO-label was later downplayed. Equinor managed to establish a commitment to IO up to the top of the company. Whether it was right to downplay the IO label remains uncertain, as the concept remains relevant even after 20 years.

The size of the community is important for having a functional platform for technology development. To avoid isolated cases and stand-alone projects, it is crucial that top management owns the concepts and creates a shared understanding of the fundamental concepts and the direction of development. The transformation must be large enough for the change initiative to endure over time.

Mindset also relies on "believing" in the change. This requires that new concepts are understood, and the leader comprehends enough to see the opportunities in the change and can articulate these opportunities in their own words. (Ref. CEO K. Hove in Trond's presentation).

👍

2 Like reactions. Regarding Valemon manning model changes and overall FTE reductions, how were employees used when not manned? Were they rotated to other positions during the time away?

***Valemon** was a new rig with extensive instrumentation. Employees are moving to another installation within the same company and the new positions in the onshore organization.*
There is great value for the company in utilizing those who have been involved in the change across the company and Equinor actively encouraged these people to move around the company.

1 Like reaction. If "healthy loop is not satisfactorily covered in today's governing and regulatory documents," then has this prevented you from stopping or deferring maintenance activities until regulatory requirements are changed?

Regulators currently trust manual function testing. This has become standard.
We are laying the foundation by retaining sensor data from normal situations that would normally be obtained through manual function testing. Statistics on failure modes (for each equipment component) form the basis. Condition data collection can just as easily be done digitally as manually. (This also affects the quality of the equipment since unecessary wear from the manual intervention is avoided).

1 Like reaction.1 Do you share training between companies, based on similar equipment at each site?

I would like to know if the significant reduction in maintenance activities had any short or long term reliability impacts? I would also like to know if your data and sensors are reliable enough for condition based maintenance? We struggle with sensors out of service and with data that is unusual but leads to retraining our models instead of performing work on the equipment, so automatically generating work orders would lead to wasted resources.

There must be control over data collection at tag level and control that data quality is adequate. Quality cannot be assumed, but data flow must be tracked from the PLC, via the transmitter and to server and IMS. This involves checking governing documentation and checking at every level of data collection. CBM is totally dependent on this being set up correctly.

Question 1

For this change, what type of cultural change did you have to go through to bring people into the digital world? As well as the difference between those that have to work onsite and those that are not. Background: we see emotional impact with people that work on sites where there are support staff that work from a remote facility or teleworking from home. Also, many of our craftspeople do not like working with technology in the field. Maybe in Norway, this is less of an issue, but if you had to overcome that, how you did would be great info.

Stepwise process – over time
Core message – what we want, with what purpose, and how to achieve it.
"Strong involvement" – Workshops, etc. didn't work so well. What worked was clear leadership with a strong core message. Moving forward, it is about repeated actions – and having a consistent message.

Leaders at every level must understand the core concepts and articulate this at their level (relevant for those executing). They must understand how to interact and make others better. Here, middle-level management understanding the concept is key to success. This level in the organization is also where contractors and vendors are followed up on in day-to-day work.

***Failure: Visiwear** (on-line cameras carried by the field technicians) did not work – it was intended for remote support, but failed. Operators felt like being remotely controlled by the people in the central office. However, today the The Visiwear failure serves as a valuable learning example.*

More successful: All field operators were trained and informed that tablets were available. The usefulness was concretized through functions that benefited the users. Functions were introduced with the *expectation of use, and they couldn't be reverted. This represented a significant enough change to make it stick.*

Field operators are used to check the status of signals from valves. The Integrated Operations Control Team can communicate directly with the facilities to confirm or deny the status. There is a mutual understanding that both sides contribute something useful. The ***IOC (Integrated Operations Center)*** *greatly benefits from this linkage for the final verification of a problem through this collaborative mechanism. It's important to identify situations where this approach is useful.*

Question 2

You mentioned earlier about forming integrated team crews versus discipline specific crews. Can you elaborate on this? Is this like 2 mechanical, electrical, I&C craft, plus an engineer, foreman, and supervisor, etc?

A culture where isolation was allowed hindered integration across disciplines. Downsizing opens and forces more collaboration. LEAN creates value through interdisciplinarity. Multiskilling means that you must understand and know something about adjacent disciplines. This is to recognize when you need to consult the other discipline. In the IO facilitation work, efforts were made to create common arenas for the disciplines to meet. Likewise, effort was also put into the rotation of personnel between onshore and offshore to give offshore people an overview of resources in the onshore organization.

A lot of maintenance was transferred to multidisciplinary teams in the campaign model for maintenance.