INPO Event Report	Level 2	21-4, Revision 1

Issue Date: December 03, 2025

IMPROVING PLANT RELIABILITY

REVISION 1 SUMMARY

Since 2021, actions taken in response to INPO Event Report (IER) L2-21-4, *Improving Plant Reliability*, in part, have reduced consequential events. However, some more serious events, such as those driven by risk factors, remain largely unchanged, underscoring persistent gaps in risk recognition, risk decision-making, and a bias to accept or mitigate rather than eliminate risks (see Figure 1). In addition, about one-third of all consequential events are linked to proficiency management shortfalls, which prompted release of INPO 24-001, *Proficiency, Advancing Human and Organizational Performance*, in February 2024. Despite its release nearly two years ago, proficiency-related events have not significantly reduced, indicating that the standard is not yet fully implemented. This revision of IER 21-4 incorporates tenets of both risk and proficiency to further improve plant reliability.

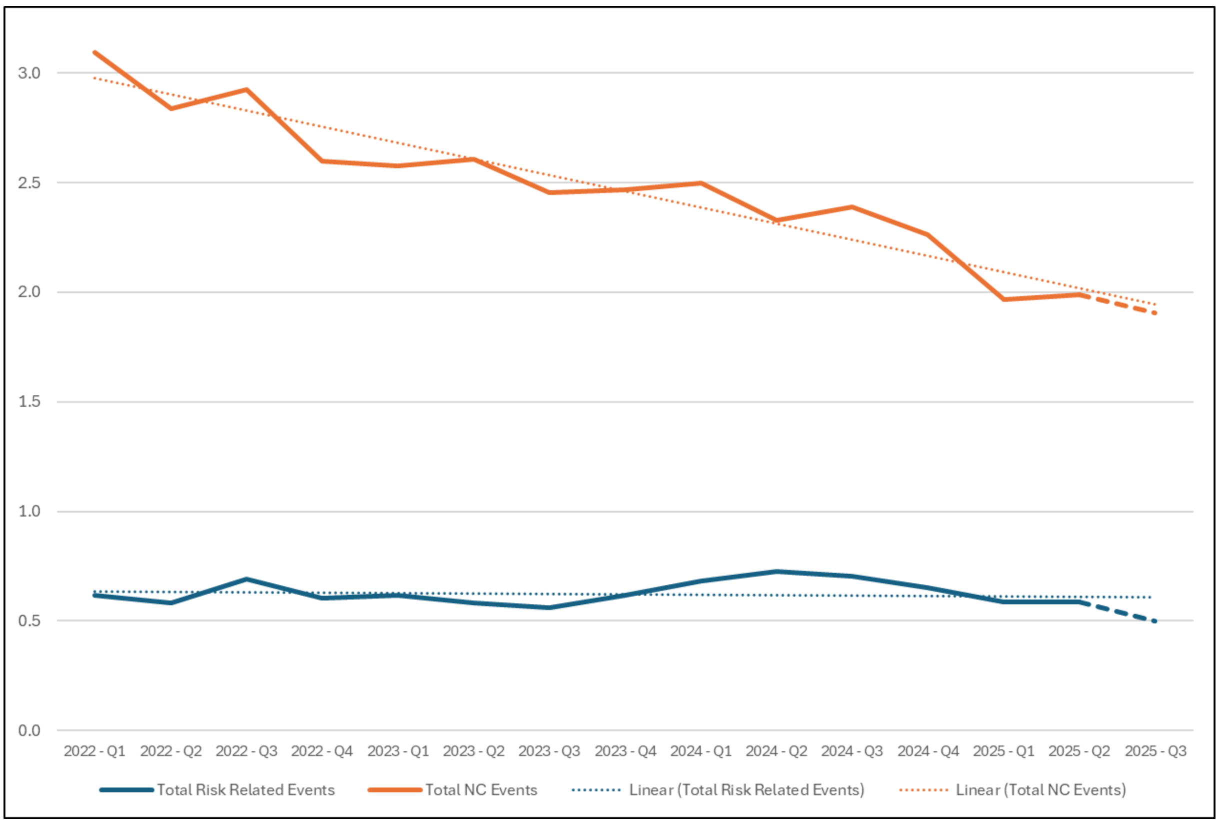

Figure 1: Noteworthy Consequential Events (Rolling 4-Quarter Average - Unitized)

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This revision is not a complete rewrite of existing guidance, but rather it clarifies or adds recommendations to incorporate proficiency, risk, and elements of SOER 2025-1, *Improving Equipment Reliability at Nuclear Facilities*. The recommendations also leverage continuous improvement principles to reduce events involving operational risk.

The events described in the 2021 issuance of this IER remain relevant and important because of their significance, their industrywide applicability, and because they revealed plant reliability behaviors that must be understood and corrected to prevent consequential events.

A cross-functional industry team and INPO analyzed more recent industry performance to assess the effectiveness of previously implemented IER 21-4 recommendations. This analysis was then independently reviewed by industry executives. Together, these groups highlighted the following factors as weaknesses challenging long-term effectiveness of IER 21-4:

- Ineffective addressal of proficiency management
- Shortfalls in operational risk management that could impact plant reliability
- Weaknesses in the use of operating experience to inform decision-making

OVERVIEW OF CHANGES

The following describes the changes included in this revision to the IER:

1. Added the *Revision 1 Summary* and *Overview of Changes* subsections to summarize the basis for the revision and explain the resulting changes.
2. Divided the *Discussion* section into the *2021 Lessons Learned* and *2025 Lessons Learned* subsections. The 2021 subsection forms the basis for the original recommendations. The new 2025 subsection forms the basis for the new recommendations.
3. Incorporated updates to select original recommendations as enhancements to improve clarity, address industry feedback, and capture recent insights (Recommendations 1, 3b, 3d).
4. Updated the *IER Process Expectations* and *References* sections to reflect the changes and improve document formatting.

Additionally, the following provides an overview of the revised and new recommendations:

1. Recommendation 1 was revised to emphasize proficiency, preventing plant reliability events and improving performance over time.
2. Recommendation 3b was revised to clarify that analysis and trending occur dynamically and to ensure a periodic review by senior management.
3. Recommendation 3d was revised to ensure teaching and learning activities are used to continuously improve organizational proficiency.
4. Recommendation 4d is a new recommendation to verify activities involving risk are identified and managed to prevent human-induced impacts to plant reliability.
5. Recommendation 8 is a new recommendation that incorporates the management of proficiency.

DISCUSSION: WEAKNESSES IN PREVENTING EQUIPMENT-RELATED CONSEQUENTIAL EVENTS

2021 SUMMARY

From 2018 through 2020, the nuclear industry averaged more than 200 Noteworthy - Consequential (NC) events per year due to equipment malfunctions or failures and the trend remained relatively flat. In some cases, significant equipment damage not only heightened operational risks, but enterprise-level risks, as well. Moreover, these consequential events were largely preventable. To improve overall industry reliability and significantly reduce precursors to more serious challenges, a renewed focus on preventing equipment-related consequential events is required. It should be noted that many behaviors associated with a strong continuous improvement culture apply here, especially those that underpin continuous learning and self-awareness and self-correction.

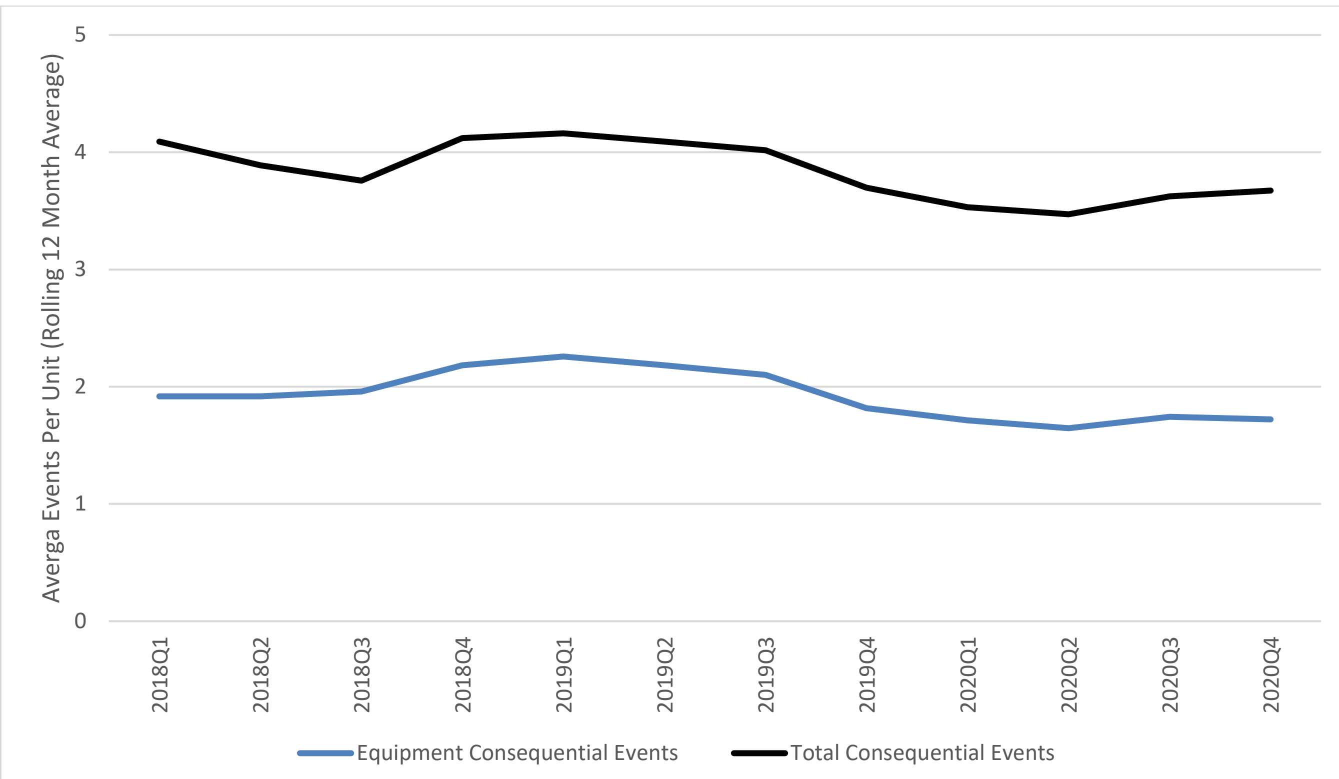

Figure 1: 2018-2020 Trend of Consequential Events in the US Nuclear Industry

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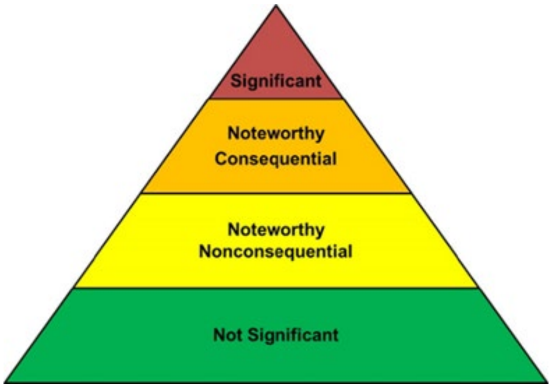
SIGNIFICANCE

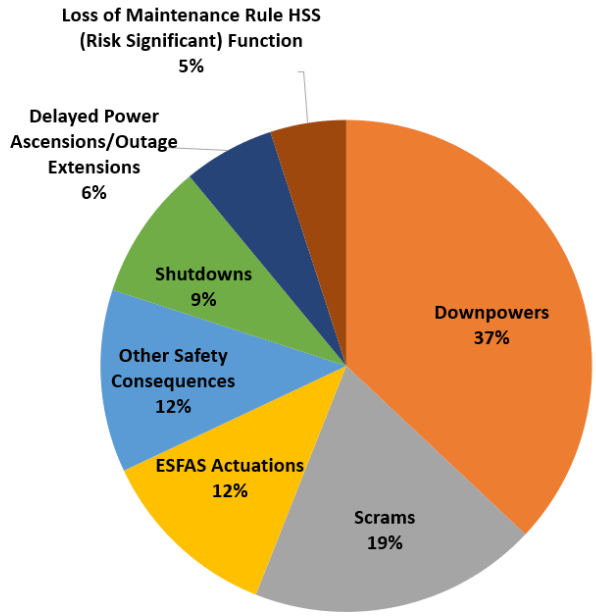
Equipment-related consequential events are those that cause an unexpected, adverse change in plant conditions with the potential to cause a reduction in plant safety or reliability. From 2018 through 2020, the nuclear industry experienced 622 equipment-related consequential events affecting industry reliability and electricity generation. Of note, generation losses from the events totaled more than 38 million megawatt hours: equivalent to shutting down the entire U.S. nuclear industry for sixteen days.



Experience has shown that the most significant industry events are usually preceded by less significant precursor events. Events are screened to determine significance levels based on their actual or potential consequences or the likelihood they are a precursor to a more significant event. From top to bottom on the Event Severity Pyramid, levels include Significant (S), Noteworthy - Consequential (NC), Noteworthy - Nonconsequential (NNC), and Not Significant (NS). The focus of this INPO Event Report is to improve industry reliability by reducing the number of Noteworthy - Consequential events that are caused by equipment degradation or failure.

CONSEQUENCES

The consequences associated with these events have ranged from the need to downpower a unit, to more serious safety system actuations or other safety consequences. This graphic summarizes the range of consequences from 2018 through 2020.



A key objective of the Operating Experience (OE) Program is to improve nuclear power plant safety and reliability by identifying event precursors so that corrective actions may be taken to prevent future events. Reporting OE promotes continuous learning by leveraging the collective knowledge of the entire nuclear industry.

2021 LESSONS LEARNED

A multi-disciplined group, from the industry and INPO, that included operations, maintenance, work-management, supplier and engineering experts analyzed the 622 equipment-related consequential events that occurred from 2018 through 2020. The events were grouped into several categories by direct cause, such as preventive maintenance, work planning, management, risk, design, and construction/installation. The group determined the main drivers behind these direct causes to be behaviors and/or programmatic weaknesses associated with:

- risk recognition and mitigation
- decision making
- oversight of vendor and supplemental personnel
- parts quality

RISK RECOGNITION AND MITIGATION

Consequential Event: At a boiling water reactor (BWR) in May 2021, a reactor recirculation pump tripped because of a faulted cable, causing entry into single-loop operation and a reactor power reduction to approximately 40 percent. Operators also noted illumination of a ground fault annunciator for the other reactor recirculation pump which was subsequently determined to have a grounded cable. The cable faults resulted from water intrusion due to packing leakage from a nearby fire protection valve.

- Engineers and operators did not recognize the risks of water intrusion into these cables.
- Operators did not identify and address leakage from the valve's packing, although evidence of prior leakage onto the same cables was present.

Consequential Event: At a pressurized water reactor (PWR) in March 2021, a feedwater heater level controller failed which rapidly pressurized a heater drain tank and caused a plant transient and power reduction to 90 percent. There was no preventive maintenance requirement to replace degraded feedwater heater controllers despite previously identified deficiencies on similar noncritical controllers during numerous cleaning and inspection activities. This controller had operated erratically before the event and maintenance technicians were unable to tune it.

- Operators, engineers and maintenance personnel did not recognize the risk of failure and elevate the issue so that the organization could engage cross-functionally, perform an operational risk review and properly prioritize the issue for correction.

Consequential Event: At a PWR in November 2020, an automatic reactor scram occurred from 42 percent power while attempting to synchronize a second motor generator (MG) set after a refueling outage. A maintenance technician had previously reassembled the MG set voltage regulator card from memory, in lieu of using the associated procedure. The lower insulator spacers were incorrectly assembled which resulted in a short to ground and an excessive current draw that affected the other operating MG set, such that all control rods inserted into the core. A post-event review noted that the associated work procedure, in-fact, lacked adequate detail.

- The maintenance technician did not consider the risk associated with reassembling the MG set voltage regulator card from memory, in lieu of using the associated procedure.
- Maintenance management did not recognize the inadequacy of the associated procedure which, if used, might have contributed to worker error.

Consequential Event: At a BWR in February 2019, an automatic reactor scram occurred from 100 percent power when a negative phase signal initiated a generator lockout. The trip setpoint for the protective relays had been changed to maintain operating margin during load imbalances. The engineering change had been developed and implemented without detailed discussions of the setpoint changes and their impacts to normal operating margins.

- Design engineers did not recognize the risk of changes to the trip setpoint for operating margins other than during load imbalances.
- Engineers and supervisors did not ensure the vendor-developed engineering product had undergone critical review and verification during its preparation and development.

In these and many other similar consequential events, workers and first-line leaders either did not recognize or mitigate risks when assessing degraded conditions or implementing preventive maintenance strategies. Additionally, they did not proactively reduce risks when performing maintenance or implementing the design change process. Often, lack of preparation by maintenance craft and supervision and deficient work instructions along with shortfalls in risk recognition contributed to improperly performed tasks. In other cases, design engineers and managers did not ensure adequate reviews were conducted to identify new vulnerabilities or confirm that margins were adequate to prevent failures. Because workers and first-line leaders often did not encourage cross-functional challenges to occur, opportunities for fully assessing risks were reduced.

DECISION MAKING

Consequential Event: At a PWR in March 2021, a main feedwater pump tripped resulting in an automatic reactor power runback to approximately 60 percent. The trip occurred when moisture from a gland seal leak intruded into a servo valve which subsequently failed, causing a loss of speed control. Previously, there had been multiple instances of high servo differential pressure and oil sample results confirmed the presence of water.

- Despite evidence of a degrading servo valve, site leaders did not act decisively to ensure the specific degradation was fully reviewed and understood, including the potential consequences of failure. As a result, no actions regarding risk elimination/hardening/mitigation were implemented.

Consequential Event: At a PWR in December 2020, an automatic reactor scram occurred from 100 percent power when a fault was introduced on a unit auxiliary transformer nonsegregated bus due to moisture intrusion. Moisture entered via an improperly sealed bus duct penetration from original construction. The mitigation strategy to repair and replace insulation during condition-based preventive maintenance inspections was ineffective in preventing moisture intrusion from this duct penetration.

- In deciding on a mitigation strategy, senior leaders did not validate through physical examination or testing that the penetrations were installed per design (a key assumption).

Consequential Event: At a PWR in July 2019, an automatic scram occurred from 100 percent power when a main steam isolation valve (MSIV) spuriously closed because of moisture-induced corrosion of the microswitch. Following several prior MSIV-related reactor scrams, management decisions focused solely on mitigating rather than eliminating their causes.

- Senior management decisions to mitigate, rather than eliminate, causes of MSIV failures likely precluded a re-analysis of the single-point vulnerability (SPV) strategy that should have revealed risks associated with this microswitch.
- Senior managers did not address broader organizational shortfalls that had normalized a limited response to repetitive MSIV failures.

In these and other consequential events, senior corporate and site leaders generally lacked a consequence-bias when addressing the risks associated with degraded equipment. Rather, they allowed probability determinations to influence their decisions to accept risk and not pursue hardening or elimination strategies that would have prevented these events. Of note, 67 percent of the scrams from 2018 to 2020 could be attributed to decisions to live with or mitigate, rather than eliminate, equipment risks. This tendency to accept undue risk was evident in both short- and long-term equipment strategies and often resulted in repetitive equipment failures.

OVERSIGHT OF VENDOR AND SUPPLEMENTAL PERSONNEL

Consequential Event: At a BWR in November 2020, electrohydraulic control (EHC) fluid was discovered leaking out of the lower, outboard inspection port on a governor valve actuator. Operators initiated a power reduction and scrammed the reactor from approximately 75 percent power in accordance with procedure. The actuator was new and had been replaced in the most recent refueling outage. Detailed measurements indicated that the actuator inspection port cover plate holes were not threaded deeply enough to meet vendor specifications. One bolt was bottomed-out and lacked tightness for an adequate seal.

- Oversight shortfalls by utility and vendor personnel allowed the error to go undetected during on-site installation by the vendor.
- The vendor work package did not contain specific instructions for verifying correct fit of the cover plates during installation.

Consequential Event: At a BWR in August 2020, operators manually scrammed the reactor in response to power swings because of control valve oscillations. During a system upgrade, work packages were implemented without necessary work instructions. Additionally, some steps were not performed, and other tasks did not conform to vendor-approved information.

- During the owner review and acceptance process, utility project engineers did not adhere to a systematic and rigorous configuration change process.
- Site staff did not verify and validate the quality of the valve actuator assemblies.
- Due to lack of utility oversight, supplemental workers did not adhere to utility standards and expectations when performing important work activities.

Consequential Event: At a BWR in June 2020, the reactor and turbine were shut down to identify, inspect, and repair the cause of degrading condenser vacuum and increasing turbine exhaust hood temperatures. An investigation identified a missing casing center manway which resulted in high temperature steam impinging on the inside of the exhaust hood. Supplemental personnel did not properly install a lock plate which allowed the thread engagement to relax and the manway to fall out of place.

- Due to lack of utility oversight, staff were unaware that supplemental workers did not follow an important step in the procedure resulting in the error.

In these and other consequential events, poor utility engagement with and oversight of original equipment manufacturers (OEMs)/vendors and supplemental workers adversely impacted plant reliability. This has included key plant components such as large motors and pumps, turbines and generators. The consequences of these failures have ranged from downpowers to shutdowns and even major rework that posed enterprise-level risks to the utility. In many cases, utility staff did not engage with OEMs and vendors throughout design, fabrication, testing, and refurbishment activities to ensure quality and design requirements were met. Several plant transients or scrams resulted from missed critical attributes in work package detail, including steps requiring verification to support field installation and testing. In other cases, utility staff lacked the knowledge and experience to challenge their vendors or provide quality oversight of supplemental services.

PARTS QUALITY

Consequential Event: At a PWR in March 2021, during power ascension following a refueling outage, a main feedwater regulating valve failed closed, resulting in an unanticipated loss of flow to the steam generator and a manual reactor scram from 38 percent power. The cause of the valve closure was a premature internal failure of a new positioner while the redundant positioner was out of service. The failure was the result of debris being introduced during the vendor assembly process.

- The part had not been tested in the Parts Quality Initiative Program because feedwater regulating valves have redundant positioners.

Consequential Event: At a BWR in September 2020, an operational transient occurred when six individual feedwater heaters tripped and operators were required to lower reactor power to 80 percent. The initiating event resulted from a manufacturing defect in a circuit board on a heater drain tank level controller.

- The components were procured commercial grade in small quantities without inspection or testing.

In these and other consequential events, receipt inspections, testing, and controlled storage before installation were often not considered. As a result, quality issues with these vendor parts were unrecognized and unresolved. Many quality issues that led to parts-induced consequential events were related to balance-of-plant components such as control relays, valve controllers and positioners. In many of these cases, vendor quality controls were lacking and defective parts were unwittingly shipped to utilities. Utility and site procurement staff have not consistently required vendors who provide parts and components that could affect plant reliability to have the necessary controls in place to ensure high quality components are supplied to the nuclear sites.

ATTAINING AND SUSTAINING HIGH LEVELS OF PLANT RELIABILITY

It is vital that the behaviors associated with preventing equipment-related consequential events be embedded in nuclear industry culture, such that they will be sustainable for the long term. As this Level 2 IER represents a new industry excellence standard, its inclusion as an excellence standard within the framework of INPO 19-003 *"Staying on Top," Advancing a Culture of Continuous Improvement* will ensure its staying power. Several other Staying on Top values, including setting direction, continuous learning and self-awareness and self-correction are highlighted here to illustrate the extent to which leader and worker cultural behaviors are impacting plant reliability.

SETTING DIRECTION

It is incumbent on corporate and site senior leaders to establish an environment in which work groups assume collective ownership and accountability for excellence in equipment performance and plant reliability. Among the numerous consequential events that were analyzed, multiple stakeholders were culpable for not recognizing, responding to and resolving the causes and contributors of equipment-related events. Had the stakeholders combined their efforts cross-functionally, it is likely that their collective input to risk assessments, analyses and action plans would have prevented these consequential events.

Senior corporate and site leaders should establish a clear expectation to cross-functionally address solutions to equipment shortfalls that could lead to consequential events. This is especially important in the design change process, preventive maintenance strategy discussions, and when preparing to oversee field work. Too often, these tasks are relegated to engineering or implemented by single departments whose knowledge is limited. As such, their risk recognition, failure mode analysis and consequence determinations are often incomplete.

Similarly, in many cases, leaders are not enabling cross-functional engagement with key OEMs/vendors. In some cases, vendors were not part of the initial risk determination process and therefore were not involved in subsequent risk identification and mitigation decisions. Particularly during in-field maintenance, design changes, and refurbishment activities, the requirement for knowledgeable utility supervision and oversight is heightened. In many cases, managers and supervisors were unaware of staff and vendor proficiency gaps and did not ensure the right resources were on hand.

CONTINUOUS LEARNING

In most of the consequential events analyzed, senior managers and site staff did not fully leverage operating experience (OE) and industry best practices. As a result, proficiency mitigations, decisions on maintenance strategies, failure modes and effects analysis, critical thinking, and work instructions lacked the insights OE would have provided. In some cases, personnel incorrectly considered an OE document irrelevant if it referred to similar, but different equipment than their plant configuration. In these cases, closer examination would have identified functional similarities and behavioral or programmatic weaknesses similar to their situation.

The consequential events analyzed revealed weaknesses in learning from and implementing the following:

- INPO 18-001, *Leveraging Operating Experience*
- INPO 15-011, *Principles for Excellence in Integrated Risk Management*
- INPO 14-005, *Principles for Excellence in Nuclear Supplier Performance*
- INPO 10-005, Revision 1, *Principles for Maintaining an Effective Technical Conscience*
- IER L1 14-20, *Integrated Risk – Healthy Technical Conscience*
- IER L2 16-9, Revision 1, *Risk Management Challenges*

Prevention of equipment-related consequential events requires application of all possible sources and methods of advancing individual and institutional learning.

SELF-AWARENESS AND SELF-CORRECTION

Self-Awareness: In many cases, managers, supervisors and workers lacked awareness of the factors that led to these consequential events. In some cases, a lack of cross-functional engagement limited their awareness and ability to comprehensively address the equipment issues. At other times, their inability or unwillingness to probe more fully into the issue was limiting. Finally, the elements of proficiency were often in play leading up to the events. In all cases, these issues adversely impacted the level of awareness needed to enact plans that would have prevented the consequential events from occurring.

Self-Correction: When leadership was aware of equipment deficiencies, they often did not leverage the proven tools and processes, such as technical reviews, SPV elimination or hardening, comprehensive plant reliability improvement initiatives, or Gap, Driver, Action and Result (GDAR) techniques to accelerate correction. Often, broader institutional behaviors and programmatic weaknesses contributed to incomplete investigations into equipment deficiencies and events, frequently limiting corrective actions to the direct causes of events and not addressing the underlying drivers to prevent repeat failures. Additionally, other key stakeholders, such as vendors, were often excluded from causal investigations and development of corrective actions, or did not receive feedback from parts failure investigations, receipt inspection results, and parts quality trending. As a result, corrective actions were limited in scope.

2025 LESSONS LEARNED

While the overall number of Noteworthy-Consequential (NC) events improved following implementation of this IER in 2021, the number of NC events involving gaps in managing risk has not improved. The industry continues to experience risk-related NC events similar in frequency and consequence. Many of these events are induced by personnel action or inaction during preparation for and the performance of activities that involve operational and project risk. These human performance shortcomings reveal proficiency weaknesses and involve operations, maintenance, projects, engineering and work management.

Other NC events are occurring because managers and supervisors are not managing proficiency up, down and across the enterprise. These organizational shortcomings reveal gaps in the ability to recognize and mitigate proficiency shortfalls. The following examples of recent risk-related NC events illustrate gaps in identifying the combined risk of foundation-challenge factors and matching appropriate mitigations through the lens of INPO 24-001.

RISK MANAGEMENT EVENTS WITH PROFICIENCY CONTRIBUTORS

For each consequential event, risk drivers will be contained in the bulleted narrative and proficiency contributors within parentheses.

Consequential Event: At a BWR in March 2024, a manual reactor scram occurred from 35 percent power when a reactor feedwater pump tripped due to an introduction of air into the system through a boundary valve. In developing a clearance for the emergent isolation of a condensate pump under vacuum with a degraded seal, operators selected and executed a wrong procedure section.

- The operators involved in clearance development did not have experience in isolating the condensate pump under various plant conditions and were unaware of a specific procedure section that was developed based on prior station operating experience. In this case, circumstances that should have led to a decision to more deliberately analyze risks did not occur (proficiency foundation shortfalls - knowledge and familiarity).
- The procedure section for isolating a pump under vacuum was included as a separate, standalone section and was not referenced within the main procedure section for shutting the pump down. The failure to be overt in leading operators to the specific procedure for this evolution inserted risk that, in this case, resulted in a consequential event. Lastly, had risk management been executed for this evolution, it is likely that the correct procedure would have been discovered (proficiency challenge shortfall – deficient procedure).
- Operations supervisors assumed that “others” in the organization had considered risk when approving the emergent activity to repair the condensate pump, so they did not personally conduct an operational risk review. They believed that an earlier evolution to shift the condensate pumps to support the repair was the ranking risk, which had already been completed satisfactorily. In this case, risk management

deficiencies included an “assumption” of risk review without verification, and a risk comparison that did not consider the risks specific to this evolution (proficiency challenge shortfall – overconfidence).

Consequential Event: At a PWR in November 2024, a manual reactor scram occurred from 100 percent power following a trip of the main feedwater pump. Previously, maintenance technicians conducted an emergent replacement of a component to correct an alarm-condition but selected an incorrect software option which tripped the pump.

- The maintenance team over-relied on a subject matter expert that did not realize the procedure lacked sufficient detail and verification steps. In addition, the maintenance team did not recognize that the maintenance training simulator did not accurately model the plant in these circumstances. Each of these factors inserted risks into the evolution, which should have prompted a thorough risk review, but did not (proficiency foundation shortfall – knowledge; challenge shortfalls – procedure and simulator deficiencies).
- Operators, engineers, and maintenance personnel did not conduct a thorough, cross-functional risk review of the activity and so technicians were unaware of potential effects of the component replacement on other operating systems. A factor in electing to bypass a thorough review were past successes in performing similar component replacements (challenge shortfall – overconfidence).

Consequential Event: At a PWR in May 2025, a manual reactor scram occurred from 100 percent power due to an incorrect selector valve manipulation which tripped a feedwater pump. Lube oil temperature had been elevated for more than seven weeks with the temperature control valve fully open. While attempting to shift lube oil coolers and lower the temperature, an operator over rotated a three-way selector valve (that had a broken mechanical stop), restricting oil flow to the bearings and tripping the pump.

- Operators and engineers did not communicate cross-functionally to address the adverse lube oil temperature trend, but rather accepted the risks posed by the higher temperatures for nearly two months (challenge shortfall – organizational complacency).
- The operations team did not apply risk management to this evolution, though it occurred with oil coolers in-service and represented a potential single point vulnerability (challenge shortfall – inadequate preparation).
- The operator was not familiar with the valve stem indications (indentions) that signified flow paths, and so risked mispositioning the selector valve regardless of the broken mechanical stop (proficiency foundation shortfall – knowledge and skill).
- The operations team in the field was unaware of the risk imposed by the selector valve’s broken mechanical stop and the potential for and consequence of over-rotating the valve (challenge shortfall – plant status).
- The system operating procedure did not describe the risks of switching in-service oil coolers (challenge shortfall – procedural deficiency).

In these and other consequential events, breakdowns in risk awareness and proficiency involved organizations and teams down to individual workers. Taken together, they illustrated a general lack of commitment to risk management, even when they involved emergent, in-service evolutions on components and subcomponents that had the potential to scram the reactor. Proficiency shortfalls often involved concurrent “foundation” and “challenge” deficiencies in the same evolutions, greatly compounding the proficiency risks that, in turn, went unmitigated. In every case, the teams and individuals involved lacked self-awareness of the risks they posed in proceeding ahead with their assigned tasks and the result was a noteworthy consequential event.

PROFICIENCY MANAGEMENT EVENTS WITH RISK CONTRIBUTORS

For each consequential event, proficiency drivers will be contained in the bulleted narrative and risk contributors within parentheses.

Consequential Event: At a PWR in March 2025, a loss of decay heat removal occurred due to the inadvertent shutdown of the pump supplying cooling. While executing activities to enter a planned divisional maintenance window, operators failed to evaluate the consequence of a plant lineup that removed power to the operating decay heat removal pump. Reactor coolant system temperature subsequently increased until operators restored heat removal per their abnormal operating procedure.

- Station managers commenced activities to prepare for divisional maintenance prior to all cross-train work having been completed. Their awareness that this decision might have adverse consequences did not drive cross-functional analysis of plant conditions, including risk management, and revealed foundational proficiency weaknesses across the management team (risk management shortfalls – did not recognize the need for risk analysis in the first place, failure to manage multiple concurrent activities that were not compatible).
- Operations personnel continued with the evolution without correcting deviations from station standards but were confident based on past successes and perception that risks were low. Proficiency was challenged by an unwarranted confidence level which resulted in poor judgment (risk management shortfalls – failure by operators to consider the need for a more in-depth risk review, failure to consider the possible consequences of plant conditions on heat removal pump operations).

Consequential Event: At a BWR in March 2025, an automatic reactor scram occurred from 97 percent power when a reactor feed pump (RFP) tripped due to low suction pressure. Following an extended power uprate, low margin conditions in the circulating water system worsened, such that air binding had occurred fifteen times since 2022. Operational guidance required personnel to apply condenser cleanliness strategies to prevent or mitigate the onset of air binding.

- Cross-functional challenges during operational decision-making did not accurately assess the consequence of backflushing, which had been previously successful under different conditions. In this case, the foundational knowledge and skill of the cross-functional team to probe the aggregate conditions in which the backflush evolution would occur fell short and the backflush was not successful (risk management shortfalls – failure to assess and eliminate or mitigate aggregate risks).

- Maintenance and work management personnel did not identify and communicate an equipment deficiency on an important valve that added water to the hotwell. As a result of operators being unaware of this plant status challenge to their proficiency, they were unprepared when the component malfunctioned and failed to mitigate the RFP low suction pressure condition (risk management shortfalls – failure to conduct detailed, cross functional risk analysis involving maintenance, work management, and operations which would have highlighted the valve's status).
- A previous, severe air binding event in December 2024 resulted in an operational decision to dredge the intake structure. During that evolution, organizational proficiency challenges were revealed that were more or less repeated in March 2025, indicating a lack of follow-up to correct latent organizational proficiency shortfalls (risk management shortfall – failure to recognize, eliminate, or mitigate latent organizational proficiency risks).
- Low margin conditions in the circulating water system were well-documented, understood, and had led to multiple air binding events. Nonetheless, the organization elected to tolerate this adverse condition which repeatedly challenged the proficiency of operators, rather than implement design improvements or other strategies to better manage low margins (risk management shortfall – failure to eliminate or mitigate the proficiency risks to operators posed by low margins in the circulating water system).

In these and other consequential events, proficiency shortfalls are widespread and range from the overall proficiency of the organization to the proficiency of cross-functional teams to individuals. In many cases, the proficiency challenges are unrecognized and what is most evident is the lack of in-depth understanding and application of proficiency management. Finally, in some cases, proficiency challenges are known and tolerated, without any deliberate effort to relieve operators of a burdensome plant condition that would eventually lead to a noteworthy consequential event. When these conditions persist, risks are widespread and often involve compounded, foundational shortfalls and challenges that amplify proficiency risks. Lastly, these consequential events, once again, reveal a lack of sensitivity to circumstances that should trigger risk reviews in the first place, and a general indifference for implementing risk management at all.

PROFICIENCY AND RISK IN ACHIEVING SUSTAINABLE PLANT RELIABILITY

In the preceding examples, managers and supervisors did not manage proficiency. In most cases, they failed to recognize foundational and challenge elements of proficiency at all, indicating either a broad lack of understanding of the concept of proficiency management or disregard for it. In other cases, if mitigation measures were implemented, they were inadequate and failed to prevent the consequential event.

Similarly, these events reveal a striking disregard for risk management. In every example, multiple risks were present, including proficiency risks, and were either unrecognized or ignored. Rather than valuing risk reviews, these organizations sought to rationalize why they might avoid them. The absence of skills demonstrated in these examples, such as risk recognition, judgment in determining that a combination of factors warrants a more deliberate review, and self-awareness to know when to involve others in decision-making, should be concerning to every reader.

The intent of this revision is to highlight that risk management and proficiency management are both critical to reducing consequential events- including scrams – while improving plant reliability and strengthening industry performance and sustainability through actionable recommendations. However, the analysis of these events reveals a deeper problem. The extent of dysfunction in effectively applying risk and proficiency principles illustrates why risk-related and proficiency-related consequential event rates have not improved. Until both these excellence standards are more deeply understood and more broadly applied, our industry will continue to experience unacceptable numbers of noteworthy consequential events. The recommendations that follow are a start. It is incumbent on corporate and station leaders across the industry to redouble their efforts to more deeply understand and more fully apply the tenets of risk management and proficiency management up, down and across their organizations.

RECOMMENDATIONS

Each one of these recommendations requires senior leadership to assign action at an organizational level, assuring that authorities and accountabilities to fully accomplish each task are in place. To ensure these recommendations serve to pursue excellence in plant reliability and are sustainable, they must be institutionalized. As this IER represents a new standard of industry excellence, its addition within the framework of INPO 19-003, *Staying on Top - Advancing a Culture of Continuous Improvement*, is an ideal means of ensuring it is captured within the culture of your organization and is sustained.

1. SET DIRECTION

Senior corporate and site leaders set and communicate a clear vision and strategy focused on preventing consequential events by developing and sustaining strong organizational proficiency. They consistently demonstrate and reinforce this direction, ensuring that the behaviors of all employees support lasting plant reliability. (Revised)

2. APPLY CONTINUOUS LEARNING

Senior leaders ensure that managers and site staff fully leverage operating experience (OE) and industry best practices when determining solutions to equipment shortfalls that could lead to consequential events.

3. IMPROVE SELF-AWARENESS AND SELF-CORRECTION

a. Conduct cross-functional analysis of systems, structures and/or components that have been the predominant contributors to equipment-related consequential events at your utility/station over the past three years, including extent of condition. Analyses should consider data from other stations (based on fleet membership, Nuclear Steam Supply System (NSSS) design and vintage) to identify equipment populations that are most likely to contribute to equipment-related consequential events.
b. Ensure event trending reviews include input from cross-functional stakeholders and vendors. Use internal and external operating experience (OE) to regularly update the list of systems, structures, and components (SSCs)

described in Recommendation 3a as new vulnerabilities are discovered or existing ones are resolved. Senior managers should formally and cross-functional challenge and validate this event trending process at least once per year. (Revised)

c. Ensure organizational and programmatic evaluations include cross-functional stakeholders (e.g., supply chain for parts failures, OEMs, vendors) and identify the drivers for equipment-related consequential events. At a minimum, employ GDAR techniques for completeness.

d. Continuously improve organizational proficiency through teaching and learning on proficiency management, roles, responsibilities and decision-making. Emphasize self-awareness in managing proficiency and assessing proficiency at all levels down to the individual. Advance critical thinking and judgment in determining foundation-challenge factors and applying mitigations. Incorporate proficiency-related operating experience into the teaching and learning activities. (Revised)

4. STRENGTHEN RISK RECOGNITION AND MITIGATION WHEN PREPARING FOR AND PERFORMING TASKS

An important tenet of risk identification is assuring that the governance for any task is defect-free. Thorough reviews of applicable maintenance work instructions, procedures, and troubleshooting guides must validate their sufficiency to guide the worker in executing a task without error. To assist in raising risk awareness, steps that if improperly executed could impact plant reliability should be identified and their completion overseen by a supervisor or subject-matter-expert. Utility and site leaders must ensure that a review of applicable work documents consistently accompanies risk reviews. The following recommendations apply to activities on equipment that could contribute to a consequential event:

a. Validate that work management and operational decision-making activities conduct risk management reviews that include relevant OE and consequence determinations for degraded equipment.

b. Direct that preventive maintenance strategies include cross-functional risk management input, operating experience and vendor recommendations.

c. Direct that design change processes include cross-functional risk reviews that incorporate Failure Modes and Effects Analysis or similar process, detailed reviews of procedures and directives, and third-party reviews.

d. Validate that supervisors and workers accurately assess and appropriately mitigate the combined risks of proficiency foundation-challenge factors for the teams and individuals performing planned and emergent work involving operational and/or project risks. (New)

5. ENHANCE RISK-ELIMINATION BIAS IN DECISION MAKING

Ensure corporate and site leader’s decisions demonstrate a risk-elimination bias when addressing degraded conditions that may result in a consequential event. Verify that governance and agendas for forums that address emerging equipment issues, such as work management, strategic plant health, and operational decision-making include the following:

- Results from cross-functional participation in risk reviews and specific recommendations

- Reviews of relevant operating experience
- Risk management consequence determination
- Effects of coping with both short- and longer-term equipment degradation or failure
- Considerations for risk elimination or hardening vice mitigation and bridging strategies

6. ESTABLISH A SUSTAINABLE PARTS QUALITY PROCESS

Validate that standards to procure, inspect, and test parts for equipment whose failure may result in a consequential event, consider the consequence of degradation or failure of that specific part. Ensure the resulting treatment of the part is tiered according to its consequence determination, such that higher consequence parts undergo increased scrutiny in procurement, inspection protocols, and testing to minimize their probability of failure. Both internal and vendor trending data, if available, are important elements in this determination.

7. ESTABLISH HIGH STANDARDS IN VENDOR AND SUPPLEMENTAL PERSONNEL OVERSIGHT

Utility and nuclear leaders have every right to insist that vendors perform to nuclear industry excellence standards and that they supply supplemental workers who are not only qualified, but proficient in executing the tasks they are contracted to perform. At the same time, oversight responsibility to ensure that station and industry standards are followed by the vendor and their supplemental workers lies primarily with the utility and the nuclear site staff. This is true whether the work is being performed on site, or in the vendor's production facility. Finally, vendors bring a wealth of knowledge and subject-matter expertise to the nuclear industry. Their partnership in cross-functional reviews and decision-making forums must be pursued and welcomed. The following recommendations are intended to strengthen the vendors contributions to plant reliability:

a. Oversight of Vendor Workmanship:

Verify the following protocols are in place for any vendor design change or equipment repair whose failure could result in a consequential event:

- Conduct cross-functional risk reviews of the change or repair that includes a consequence determination should failure of the modification or repair occur.
- Verify that communication and interface protocols between the utility/site project team and vendors/engineers are established at the appropriate frequency to support key project milestones.
- Confirm the proficiency of those performing owner-acceptance reviews and employ third-party reviews, as necessary. Consider scaling the above protocols in accordance with the consequence determination from the risk review.

b. Oversight of Supplemental Workers:

Verify the following activities occur at a scope and frequency appropriate for the risk/consequence associated with the task:

- Conduct a cross-functional assessment of operational risk associated with the work including a consequence determination.
- Conduct a review of relevant operating experience.
- Oversee supplemental work with an eye toward assessing proficiency of the workers and then adjust oversight/intervention as determined by proficiency/probability and consequence of failure.

8. RECOGNIZE AND MITIGATE PROFICIENCY SHORTFALLS (NEW)

High levels of individual, leader, and team proficiency are essential to achieve and sustain excellent plant reliability outcomes. This requires appropriate management of all three elements of the proficiency model and their associated factors in accordance with the framework of INPO 24-001, *Proficiency, Advancing Human and Organizational Performance*. Given the variability in proficiency driven by ever-changing human factors and external conditions, individuals, leaders, and teams must remain self-aware of their proficiency status, leverage operating experience, and exercise real-time risk management to perform effectively in their roles. Teaching and learning activities help strengthen the knowledge and understanding of risk standards and build the skills needed to recognize challenges to proficiency and apply appropriate mitigations, as prescribed in Recommendation 3d. The following recommendation is intended to ensure leaders recognize and mitigate proficiency shortfalls to prevent consequential events that impact plant reliability:

- Direct that managers and supervisors continuously monitor, assess and maintain the proficiency of the workforce, including nuclear professionals at all levels of the organization, vendors and supplemental workers. Anticipate and manage foundational proficiency shortfalls when individuals transition into new roles in the organization.

IER PROCESS EXPECTATIONS

This Level 2 INPO Event Report (IER) addresses an important adverse performance trend, and the recommendations require timely implementation. Each station is expected to review the recommendations provided in this document and to develop corrective actions.

- All WANO-Atlanta Center stations are expected to fully implement this IER.
- For stations that were previously assessed on the original Revision 0 recommendations of this IER, implement the new recommendations and revised recommendations.
- Define corrective actions within 120 days (April 03, 2026) of the IER issue date (December 03, 2025).
- Inform INPO of corrective action implementation plans within 150 days (May 04, 2026) of the IER issue date.

Personnel from INPO will review implementation plans and actions taken in response to this IER. A cross-functional team will perform a collaborative review of the information sent to INPO. Feedback will be provided to stations on an as-needed basis. Personnel will review ongoing corrective actions during peer reviews, continuum activities, or focused review visits. The reviews will commence following corrective action submittals to INPO. Send final implementation plans to INPOIERResponse@INPO.org, or send a hard copy to the Vice President, Data & Analytics. Acceptable implementation plans for responding to IER recommendations are described in INPO 10-006*, Operating Experience (OE) Program and Construction Experience (CE) Program Descriptions*, and in the accompanying *IER L2-21-4 Industry Response Template*.

REFERENCES

The following provide reference information for the details included in this IER:

- INPO 19-003, *Staying of Top, Advancing a Culture of Continuous Improvement*
- IER L1-14-20, *Integrated Risk*
- IER L2-11-2, *2009-2010 Scram Analysis*
- IER L2-17-9, *Weaknesses in Maintenance Technical Fundamental Skills Adversely Affecting Plant Operation*
- IER L2-16-9, Revision 1, *Risk Management Challenges*
- INPO 18-001, *Leveraging Operating Experience*
- INPO 10-005, Revision 1, *Principles for Maintaining an Effective Technical Conscience*
- INPO 16-009, *Critical Parts Quality and Availability*
- INPO 14-005, *Principles for Excellence in Nuclear Supplier Performance*
- AP-930, Revision 4, *Supplemental Personnel Process Description*, Appendix B: *Mitigating Strategies*
- INPO 05-002, Revision 2, *Human Performance Tools for Engineers and Other Knowledge Workers*
- INPO 20-001, *Gap, Driver, Actions That Get Results*
- INPO 14-004, Revision, 3, *Conduct of Performance Improvement* (see Appendix B, Issue Investigation)
- INPO 24-001, *Proficiency, Advancing Human and Organizational Performance*
- INPO 23-001, *Guidelines for Advancing Teaching and Learning in the Nuclear Power Industry*
- INPO 15-005, *Leadership and Team Effectiveness*
- INPO 10-005, *Principles for Maintaining an Effective Technical Conscience*
- INPO 15-011, *Principles for Excellence in Integrated Risk Management*
- INPO 21-003, *Achieving and Sustaining High Plant Reliability*
- INPO 19-002, *Industry Reporting and Information System (IRIS) Reporting Requirements*