Roadmap to Operational Readiness

A new entrant's guide to preparing for the challenge of safe and efficient nuclear power plant operation

A product of the
New Unit Assistance Working Group

A Message to Our New Colleagues

Welcome. We appreciate your plans to further expand and help evolve the world's nuclear power industry. Congratulations on your bold endeavour. Nuclear power, when done responsibly, yields numerous socio-economic benefits. It employs a fuel source that is relatively abundant and potentially infinite. As an alternative to fossil fuel, it combats climate change by reducing the release of greenhouse gases. For many countries, it serves to diversify sources of electric power and broaden the economic base. Likewise, it provides base load electric power for countries with constrained geographies and limited power production resources, thus helping to reduce economic vulnerability and political dependency.

Of course, responsibly means understanding and appreciating the unique nature of nuclear power. The unique characteristics of this industry demand that nuclear safety is the overriding priority in all aspects of your project. Designing, building, maintaining, and operating within plant safety margins requires constant vigilance. Failure to do so creates vulnerabilities that can lead to major plant events. While such events are rare, they have happened; and the consequences are terrible. The cost to your plant, your company, and your country can be horrific. Indeed, the cost of failing to responsibly manage your new nuclear plant can be extreme. Furthermore, we know that the cost and impact of any plant's failure are borne by all of us. In this industry, we are truly "hostages of each other[1]." As a new entity, and as new leaders in our community, you become obligated to us all.

The good news is we band together to engage, share, teach, evaluate and support each other. We embrace a collective responsibility with regards to nuclear safety and overall plant performance. You are not alone. We, your new colleagues in the nuclear industry, are here to help. It is in that spirit that the "Roadmap to Operational Readiness" is provided.

This roadmap is a collection and integration of industry guidance, lessons learned, success stories, and select industry reference material. All of which is designed to accelerate both your understanding of the task ahead and assist in the planning and execution on the path to safe, efficient plant operation. The New Unit Assistance Working Group is a group of your new industry colleagues who are either preparing or have prepared for new plant operation during the past decade.

We sincerely hope the lessons from our collective journeys saves you time, effort, money and angst. Most importantly though, we hope it helps you build a more resilient plant, program and organisation dedicated to safe and efficient nuclear plant operation.

The New Unit Assistance Working Group

[1] "Hostages of Each Other, the Transformation of Nuclear Safety since Three Mile Island" by Joseph V. Rees

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Section A: Introduction to the Roadmap to Operational Readiness

Welcome to the roadmap. The intent of this document is to provide a new country, a new company and/or a new plant guidance in preparation for safe nuclear plant operation. While intended to serve all new projects, this document is written assuming your project organisation has little to no nuclear experience or knowledge (e.g. a new company or organisation building a new plant in a country new to the nuclear industry). The guidance herein should also prove useful to plants recovering from either long refurbishment efforts of dormant, previous construction and commissioning efforts. This guidance strives to be comprehensive and user-friendly. Given the broad international target audience, the document strives to communicate in simple English.

The roadmap is focused on operational readiness. This document does not discuss topics exclusive to commercial contracting, design, construction or commissioning. It will, however, highlight operational principles, concerns and issues that should be considered during these project phases. This discussion can be found in Appendix 1.

The roadmap has been developed based on industry experience with the development of new large-scale nuclear generators of all types. The document is applicable to all generations of large-scale reactor design types, to include: boiling water reactors (BWRs), pressurized water reactors (PWRs), water-water energetic reactors (VVERs), high-temperature, gas cooled reactors (HTGRs), and pressurized heavy water reactors (PHWRs). The guidance herein does not contemplate the development, construction and operation of new small-scale modular reactors. While much of the content within will likely be directly applicable, it remains unknown and subject to the authorship of future nuclear operators of small-scale projects.

What do we mean by operational readiness?

The roadmap is your guide to operational readiness. We will start by discussing what we mean by the term operational readiness. Before we do that, let us take a moment to define what it is not. Operational readiness is not "ready to load fuel." Operational readiness is the state of plant, people, programs, processes, procedures, supporting infrastructure, and proven organisational performance required to safely operate the plant at power, including the ability to adequately respond to all normal and emergency conditions (e.g. response to a plant trip and execute a forced outage). This state of readiness is to be achieved prior to fuel load. While not an all-inclusive list, this state of operational readiness can be characterized by the list of criteria found in figure A.1.

Prior to fuel load, each of the criterion listed on the next page must be verified. Verification should be done in a respectful, but intrusive manner. Sufficient evidence that proves satisfactory achievement of each criterion should be captured and formally documented. A manager's report that everything is good is not satisfactory. We will discuss the topic of nuclear safety later, but for now, let us just say that the consequences of not meeting defined criteria are far too great. The concept of "trust, but verify" is a core principle of safe nuclear operation.

Figure A.1 Operational Readiness Criteria

The following criteria should be met, and verified prior to Fuel Load in preparation for safe, full power reactor operation:

Plant Licensing:

- The submission of an Operating License application to the Regulator
- The receipt of an Operating License (or Licenses) from the Regulator
- The receipt of all required non-nuclear permits and licenses e.g. environmental, health & safety
- Satisfaction of transmission grid connection prerequisites and grid operator interface requirements

Plant:

- The satisfactory turnover of all plant areas and systems to defined operational standards. Includes receipt and verification of system design, component, vendor (e.g. Bill of Materials), and master data
- The satisfactory turnover of all plant areas to defined operational standards
- The completion of satisfactory* commissioning testing of all plant components and systems
- The verification of plant component and system line up in preparation for fuel loading
- The receipt and proper storage of new fuel
- As required, the satisfactory layup and preservation of commissioned systems

People:

- The assignment of an adequately experienced leadership team
- The staffing of personnel to defined organisational target levels for each functional area
- The training and qualification of the requisite number of personnel for each organisational function
- The documentation and retention of all personnel training and qualification records

Documentation:

- The development, implementation and functional verification of all processes and programs
- The development, implementation and plant/simulator verification of all plant operating procedures
- The development, implementation and verification of all plant procedures for each function

Supporting Infrastructure:

- The implementation and functional verification of all underlying software infrastructure
- The implementation and functional verification of an underlying document and record retention program
- The collection, storage and retention of all critical plant data
- The purchase, inventory, and warehousing of critical plant spare parts
- The completion and outfitting of all required facilities (to include support for outages)
- Complete and functioning security barriers and guard force capability

Verification of Organisational Performance

- The formal demonstration and verification of satisfactory operational and plant support task performance
- A demonstrated capability to conduct a safe plant shutdown and conduct a forced outage
- The completion of planned exercises and satisfactory demonstration of Emergency Planning Capability
- The successful completion of external pre startup assessments
- The verification of an adequate Nuclear Safety Culture and a demonstrated capability for continuous learning

Notes:

1) **Commissioning and startup testing needs to ultimately meet the operability criterion of the plant's technical specifications for each safety systems*
2) *The above criteria do not include that required for plant startup*
3) *Any exceptions to the above should be identified, formally captured, and evaluated individually and in aggregate. Justified and approved exceptions should be few. Approved exceptions should be tracked for near term completion*

Source: New Unit Assistance Working Group

What is the roadmap?

The roadmap is a guide for your organisation to use as you progress from new plant project approval to safe, steady state operation. The roadmap is designed to be the one overarching document that helps pull together and integrate the entirety of industry experience, guidance, and more detailed reference material pertaining to new nuclear plant operation.

The roadmap strives to help the new nuclear leadership team get smarter, faster on topics important to the pursuit of safe and efficient plant operation. It is hoped that accelerated understanding leads to higher quality levels of operational readiness and the achievement of such in a timelier and cost-effective manner.

The roadmap will answer a number of important questions, to include:

- What is important? What are my priorities?
- Where are we going? What are we trying to achieve in the end?
- When must we get there? How long do we have to prepare?
- How will I get there? What does the journey to operational readiness look like?
- What help exists for our team? Who can we reach out to?
- What lessons learned and opportunities exist to help guide our efforts?
- How will the industry evaluate our performance?

The roadmap provides answers to these questions and more. It should both inform you and serve as a prompt to ask even more questions. Where not answered within this document, the roadmap strives to introduce you to the numerous sources of written guidance and personnel expertise ready to help you from within the industry.

Where did the roadmap come from?

The roadmap is the first major deliverable of the New Unit Assistance Working Group (NUAWG). Formed in late 2017, the NUAWG is a collaborative body established and facilitated by WANO and made up of participants from WANO, the IAEA, and the Electric Power Research Institute (EPRI) organizations, and, most importantly, by operators from more than 50 nuclear organizations from across the global nuclear community. The roadmap has been created based on the group's collective experience and expertise. The roadmap is a cross reference document that draws from multiple sources of relevant industry guidance.

While the effort includes content and input from projects worldwide, much of the content material in Revision 0 of this document originates from one specific new unit experience. There are multiple reasons for this, which include:

- The project of choice was the first new nuclear plant and new nuclear company in a new nuclear country in 30 years. Our discussion thus assumes little prior organisational knowledge and experience. The roadmap starts with the basics. By doing such, we ensure applicability to all new nuclear projects.
- The project of choice developed an operating model using IAEA safety standards and publications for the development and use of an integrated management system, a first. This is

helpful because it reinforces the need to scope and build a comprehensive, supporting operational infrastructure.[2]

- Personnel sourced for this project of choice originated from nuclear projects from more than 80 different countries. These personnel came from new plant construction, commissioning and operational readiness efforts from virtually all nuclear countries. This is helpful as a source of multicultural insights and lessons learned.

- The project of choice conducted a large-scale, formal benchmarking program to include visits and the collection of lessons learned and best practices from all major nuclear construction programs. This is helpful because the project of choice made a strong, comprehensive effort to collect, implement and use the best practices from industry experience.

- The project of choice boldly combined local ambitions and personnel, nuclear construction expertise from a second country, and western operational standards in alignment with the WANO Atlanta Centre. This is helpful because it highlights the opportunity and challenges of such an effort.

- The project needed to address a number of special circumstances, to include: the lack of an existing national nuclear infrastructure; a broad multicultural employee population; and the use of English as the standard operating language where 85% of the employee population are non-native English speakers. This is helpful because it provides insight to addressing each of these unique circumstances.

- The primary author of the roadmap is intimate with the material collected from this project.

- While it occurred later than hoped, the approach and guidance captured within has been validated by the positive outcome of an operational readiness assessment conducted by WANO in November 2019. The assessment endorsed the project of choice’s continued progress toward fuel load and plant operation.

For the above reasons, the chosen project served as a broad and deep outline of the new nuclear experience and is a rich source of relevant and sometimes unique information. It is presumed that future revisions of this document will continue to grow and benefit from additional new nuclear experience.

Who is the target audience for this document?

This document is intended for open and transparent use by all new nuclear projects current and prospective. The document is a compilation of input from nuclear colleagues the world over.

Is additional, more detailed guidance applicable to operational readiness available?

The guidance provided herein is supported and/or complimented by a large array of industry reference material and guidance documents. A master list of reference documents is included in Appendix 6. Additionally, reference material is cited throughout this document where applicable to the topic of discussion.

Additional WANO infrastructure in support of the industry’s new nuclear effort can be found on the WANO website at https://www.wano.info/new-unit-assistance.

[2] The Management System for Nuclear Installations, IAEA Safety Standards Series No. GS-G-3.5, 2009

Does similar guidance exist that is more focused on new nuclear program and project evaluation, commercial contracting, construction and commissioning?

The simple answer is YES. The IAEA is your primary resource of quality information on these topics. Refer to the IAEA website at: https://www.iaea.org/resources/safety-standards. For ease of use, refer to: https://www.iaea.org/topics/infrastructure-development/bibliography#1. This handy bibliography is a subset of all the available IAEA material that is focused on new nuclear.

WANO has only a small body of construction related reference material to offer. This includes "INPO 09-007 Principles in Nuclear Power Construction."

While the roadmap does not address this question directly, it does provide in Appendix 1 a very helpful and important list of operational considerations to be reviewed and assessed during the period and processes of project evaluation, commercial contracting, construction and commissioning.

Is this document up to date with current experiences?

The nuclear industry prides itself on being a continuous learning organisation. As such, this document is intended to expand and improve as the nuclear industry expands and improves. The initial group of authors and contributors to this document intend that it be refreshed and enhanced annually with the benefit of user feedback and content additions based on the expanding new nuclear experience.

How do I use the roadmap?

This an important question. The roadmap strives to accomplish several things for the benefit of the new operating organisation:

- Educate.
- Guide the conduct of smart and timely actions to improve the effectiveness and efficiency of operational readiness efforts.
- Create a sense of urgency that motivates performance.

In support of these three things, we conclude this document with an eight-step plan for implementing the guidance provided throughout this document. See the final section of this document entitled Conclusion: Implementing the Roadmap.

The New Unit Assistance working group looks forward to helping you prepare and execute these early steps on your journey

One final note:

For the protection of all contributors, this document and its contents has been screened and deemed in compliance with the generally established export control guidance and requirements defined by most member operators.

Key Terms and Definitions

The roadmap will use the following standardized industry terms when and where applicable:

Chief Nuclear Officer (CNO) – Standard title designation for a nuclear organisation's lead executive responsible for the entirety of nuclear operations and core supporting functions.

Graded Approach – The assessment and the subsequent categorization by level of safety significance of plant issues, program requirements or other matters. Organisational response or corrective actions are determined based on the safety significance category.

EPC Contractor – Contractor responsible for engineering, procurement and construction.

Licensed – The official authorization to operate the plant granted to an operator by the nuclear regulator. Other terms used worldwide include certified and authorized.

Peer Group – A concept used for sites with multiple plants and or a dispersed fleet of operating plants. A peer group is the collection of governance, oversight and performance leads for a specific function. The group is formed to consult on corporate governance, identity implementation and execution support, and review performance oversight assessments. Such groups aim to optimize operational performance.

Reference Plant – The plant that serves as the basis for your new project's plant design and projected performance. Serves as a rich source of operational experience and performance validation. A first of a kind (FOAK) plant will have no reference plant.

Sister Station – An operational power station whose site configuration and plant technology are sufficiently similar to provide an optimally constructive bench mark. Its existence provides an opportunity to request, agree to and participate in relevant operational training and job shadowing.

Common Industry Acronyms

General Use

AFI	Area for Improvement	ORA	Operational Readiness Assistance
AOP	Abnormal Operating Procedure	PDM	Predictive Maintenance
CAP	Corrective Action Program	PM	Preventive Maintenance
CNO	Chief Nuclear Operator	PMO	Project Management Organization (or) Office
CPO	Crew Performance Observation	OJT	On the Job Training
EAP	Employee Assistance Program	PPE	Personal Protective Equipment
ECP	Employee Concerns Program	PRA / PSA	Probabilistic Risk (Safety) Assessment / Analysis
EOP	Emergency Operating Procedure	PJB	Pre Job Brief
EPC	Engineering, Procurement, Construction	PSUR	Pre-Startup Review
ERO	Emergency Response Organanization	RCA	Root Cause Analysis
ERP	Enterprise Resource Program	RO	Reactor Operator
FOAK	First of a Kind	SAMG	Severe Accident Management Guidelines
HU	Human Performance	SAT	Systematic Approach to Training
IMS	Integrated Management System	SCWE	Safety Conscious Work Environment
KPI	Key Performance Indicator	SME	Subject Matter Expert
MCR	Main Control Room	SPV	Single Point Vulnerablity
MSDS	Material Safety Data Sheet	SRAFI	Startup Related Area for Improvement
NPP	Nuclear Power Plant	SRO	Senior Reactor Operator
OCC	Outage Control Center		
OE	Operational Experience		

Industry Organizations

EPRI	Electric Power Research Institute	NQA	National Quality Assurance
EUCG	Electric Utility Cost Group	NRC	Nuclear Regulatory Commission (USA)
IAEA	International Atomic Energy Association	WANO	World Association of Nuclear Operators
INPO	Institute of Nuclear Power Operations	WIN	Women in Nuclear
		YGN	Young Generation Nuclear

Project Phases and Milestones

CFT	Cold Functional Testing	FOC	First Operating Cycle
COD	Commercial Operation Date	FR	Fuel Receipt
ECD	EPC Contract Date	HFT	Hot Functional Test
FCD	First Concrete (safety related) Date	PA	Project Approval
FGC	First Grid Connection	PAT	Power Ascension Testing
FL	Fuel Load	R/MO	Refuel / Maintenance Outage
FO	Forced Outage	SU	Startup

Common Function Designations

EP	Emergency Preparedness	NPI	Nuclear Performance Oversight
FP	Fire Protection	OR	Organizational Effectiveness
H&S	Health and Safety	QA	Quality Assurance
HR	Human Resources	QC	Quality Control
IT	Information Technology	RP	Radiation Protection
IA	Internal Audit	RE	Reactor Engineering
NO	Nuclear Oversight	WM	Work Management

Section B: Guidance for the New Executive Team

The approval of a new nuclear plant project begins a *100-year journey. The responsible executives take on a significant obligation - like no other - to protect employees, the company, the public and the entirety of the global environment. Your obligation to a broad base of stakeholders over the coming century of nuclear operation is significant and includes:

- The creation and maintenance of an organisational culture that embraces nuclear safety as its overriding priority.
- The development and maintenance of a nuclear infrastructure that adopts and embraces stringent regulator and industry laws, codes and standards, as well as utility peer-to-peer expectations.
- An enormous financial obligation to support more than a decade's worth of expenditure prior to the realization of any revenue. This financial obligation must allow for higher than typical labour costs, early operational staffing and training, insurance and regulatory fees, industry organisation participation fees, and even the funding of long-term nuclear decommissioning costs.
- The acceptance of and accommodation for the safe and secure interim and long-term storage of spent fuel and radioactive wastes.
- The long-term need for trust and support from the public, and the reciprocal need for timely and routine engagement, education, communication and transparency by you, the operator.

(*100 years = 10 years of construction and commissioning + 60-year operating life + 30-year life extension)

What makes the nuclear industry unique?

Every industry can make a claim to being unique due to some aspect of its business. The nuclear industry is no exception. The business of making electricity via nuclear power is unique in the following ways:

- The power contained within the reactor core is immense. The consequences of mismanaging this power has proven to be devastating to the plant, the company, and the country as well as significantly impactful to the entirety of our world.
- Once taken critical, the reactor core becomes a continuous source of heat. This heat source – nuclear decay heat – must be under constant surveillance and control. The core must be actively maintained sub-critical and cooled. Failure to properly do so, even when shut down, can cause fuel damage and radioactive release.
- Nuclear plant operation creates plant radiation fields and some level of radioactive release. Active plant monitoring and protective measures are required to limit plant radiation levels and release volumes in order to minimize the dose to plant personnel and prevent public exposure.

The consequences of mismanaging these risks can be significant as evidenced by the nuclear events at Three Mile Island (TMI), Chernobyl, and most recently, Fukushima. Other near miss events, like that experienced at Davis Besse in 2002, avoided significant consequence only by good fortune. To gain a true appreciation for the devastating consequences of nuclear events, new nuclear executives are encouraged to visit and examine first-hand the local impact of both the Chernobyl and Fukushima accidents.

If not sufficiently sobering, two of the above accidents, TMI and Chernobyl, occurred very early in their operating lifetimes. Chernobyl unit 4 in its second year of operation, and TMI unit 2 in only its second month of operation. Take a moment to reflect on the immense emotional trauma a plant, company, population and country would experience and need to endure in the event of such an accident. It would be made even more excruciating by occurring at the end of a very challenging decade of construction and operational readiness preparations.

The unique elements cited above demand that every member of plant staff, supporting corporate organisations, overseeing regulatory agencies, and enabling government entities prioritize nuclear safety above all matters. Safety margins must be rigorously maintained, risks must be constantly assessed, analysed and addressed, and operational decisions must always be conservative.

For additional information, reference the WANO document entitled "The 25 Events that Shaped the Nuclear Industry."

What is your role as a nuclear operator in your new project?

The roadmap focuses on your role as the soon to be operator of a commercial nuclear power plant. But what does that mean in context to the start of your project? The basic roles for a new nuclear project can be broken down as follows: the owner, the constructor and the operator. These roles are all essential to the success of your project.

- The Owner: The entity accountable to the country and all stakeholders for the construction and safe operation of a nuclear power plant. It must bear the costs and consequences of all aspects of operation. The owner has a strong need to become an intelligent customer* of its new nuclear program and project. This need is crucial to fulfilling the owner's accountability and responsibility to provide effective oversight of plant construction, commissioning, and the operator's preparations for plant startup and longer term, day-to-day operations. Typically, the owner is the licensee for new project construction.

  *An organisation (or individual) that has the competence to specify the scope and standard of a required product or service and subsequently assess whether the supplied product or service meets the specified requirements. See reference NG-T-3.10

- The Constructor or Supplier: The builder of the plant. Often referred to as the EPC contractor, they are typically responsible for engineering, procurement and construction.

- The Operator: Responsible for the safe and efficient operation of the new nuclear plant(s). Subject to owner oversight, the operator has both the delegated responsibility and the authority to define the operating model and associated standards of operation required to meet regulatory requirements and the expectations of critical external assessment bodies. The operator plays an essential role in the oversight of commissioning and operational activities. The operator is the licensee for new plant operation.

The above roles can each be filled by separate entities OR two or all of these roles can be fulfilled by a single entity (e.g. a government or a large multi-faceted corporation).

We will take a moment to define one additional role applicable to a new industry circumstance, that of a host nation for a Build, Own, Operate project.

- Host Nation: A country that has accepted the obligation for the development and conduct of a safe commercial nuclear power program. It is the planned beneficiary of positive environmental and economic project impact. It is that entity destined to bear the local impact of the consequences of a nuclear accident AND to bear the nuclear liability of the impact to countries worldwide.[3]

In this new circumstance, a host country has delegated total responsibility for the creation and operation of a nuclear plant within its borders to another party. But it cannot delegate its accountability for the failure of this arrangement to include the occurrence of a nuclear accident and its environmental, economic and financial ramifications. In such circumstances, a significant level of competent and intrusive oversight of construction, commissioning and plant operation will be required by the host nation to help mitigate the potential for a national disaster.

While all of these roles are important, there can be a large disparity in the capability and capacity of these entities to fulfil their roles. This is particularly true in new entrant countries. For new programs, the EPC contractor is a chosen vendor who is typically larger, far more technically competent, commercially sophisticated, and the most experienced of the entities. This presents two significant challenges to the program owner. First, the owner must provide sufficient oversight of the more mature EPC contractor organisation and its activities. Second, hundreds of early program and project decisions will impact the long-term operation of your new plant. Many operational decisions will have an impact on the EPC contractor commercially and during construction. An accountable owner (or host nation), supported by responsible operational executives, must quickly become sufficiently organized and competent to meet this oversight challenge. The first of these challenges is beyond the scope of the roadmap; the second challenge will be discussed shortly.

How does an overriding priority for safety impact company executives?

Being an executive in a nuclear company requires the highest level of technical understanding, operational awareness, and conservative decision-making. Additionally, a nuclear executive must behave with maturity, emotional balance and professionalism. Executives and their organisation must distinguish itself from other industries by:

- Pursuing safety and operational excellence with passion and rigor in all direct and supporting aspects of plant operation in order to protect plant safety margins and create defence in depth for the reactor core.
- Demanding every employee and contractor behave as a nuclear professional and be accountable to living the values, demonstrating the behaviours, and executing the highest standards of safe plant operation.
- Preventing events by aggressively minimizing human errors and eliminating plant and organisational error-prone environmental elements.
- Being transparent by identifying and reporting operational events as an essential step in proper problem analysis and resolution through corrective action.
- Respecting other nuclear operators by sharing lessons learned from operational events and organisational successes.
- Welcoming and embracing (and sometimes enduring) prescribed oversight of all types to help prevent organisational complacency and minimize human vulnerability associated with the loss of objectivity that comes from operational familiarity.
- Leading a nuclear organisation is personally demanding and professionally challenging. The relentless pursuit of excellence in each and every aspect of plant operation, and the continuous

[3] The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage — Explanatory Texts IAEA

and rigorous assessment of execution against standards of perfection create an especially demanding work environment. As a nuclear executive, you will need to inspire your staff to execute consistently to the highest standards of professional performance in this especially demanding environment.[4]

What operational attributes should executives consider during project feasibility study, commercial contracting, construction and commissioning?

Numerous decisions with significant operational impact are made during early project phases. Decisions during project feasibility study, commercial contracting, construction and commissioning often have a near-term focus with less than adequate consideration of the impact on the next 100 years of operation. Poorly informed decision-making during early project phases can lead to safety concerns and have significant impacts on operational effectiveness, efficiency and cost. Smart decisions and minor expenditures early can have dramatic long-term performance impact on your business.

Accordingly, a listing of operational considerations to review and evaluate during the pre-operational phases can be found in Appendix 1 of this document.

What should be an operating executive's objective?

Your long-term objective is the safe and efficient operation of your plant(s) for the next 100 years. To achieve such requires:

- Quality construction of a well-designed plant.
- The development and implementation of processes and programs based on industry guidance and best practices.
- An organisation of highly trained and qualified individuals who are sufficiently proficient in the fundamentals of plant operation.

  Your shorter-term objective is to have achieved these three things when construction and commissioning is satisfactorily completed. You must become operationally ready.

How best should the executive team lead the organisation toward operational objectives?

From the start, a strong operational executive team will:

- Prioritize safety at all times.
- Staff the operating organisation early.
- Promote organisational learning.
- Communicate constantly.

Doing so will accelerate your efforts toward operational readiness. It will also fuel your future aspirations for performance excellence in all areas of plant operation and nuclear professionalism.

In the following section, we will discuss in much more detail the operating end state you are working to design, develop and implement.

[4] WANO Performance Objectives & Criteria, PO&C 2019-1

Section C: Building Your Operating Model

Starting with the End in Mind

A wise person once said, "If you don't know where you are going, any path will get you there." True and profound. Accordingly, defining your end state is critical to building and maintaining a nuclear operation that yields the performance results you desire. No recent new nuclear project has been planned and pursued that projects mediocre results. These projects always project strong future performance – yours will too. So, your end state must ensure this.

We will discuss the concept of an end state using the term operating model.

Why is an operating model important?

The term operating model was first introduced in the 1990s by a company struggling to operate a large fleet of nuclear power plants. In the preceding decades, this fleet of BWR and PWR plants had in all cases performed well below the potential of each plant, and in many cases, the plants were some of the industry's worst performers. Management of these plants during these decades was characterized by a distributed model of plant authority, low levels of standardization, little to no plant to plant cooperation, and highly ineffective leadership. In the '90s, new and strong leadership began a renewed journey to operational excellence. The approach employed included intrusive centralized leadership, the creation and leveraging of standardized ways of doing business, expectations for incorporation of fleet wide learning and corrective actions, and a demand for strong personal accountability by leaders and workers. By the early years of the new century, the approach was yielding strong performance results by every plant regardless of operating age or nuclear technology type.

The subsequent creation of a formal management model (what we will refer to as an operating model) was the outcome of a response to three key needs. First, there was a desire by the senior leadership of the organisation to both sustain recent performance gains and prevent a return to prior decades of poor corporate and plant performance. Second, over this long period of low organisational transparency and broken corporate promises, the regulator had grown wary and suspicious. To build regulatory credibility, there was a need to communicate how recent performance gains had been achieved and how such would be sustained in the long term. Third, and finally, a contemplated large-scale corporate merger created an immediate need to define, communicate and replicate what had been done with the existing fleet and what would be expected of members of the expanded fleet. These three needs were the impetus to capture and codify what had been done so effectively executed in recent years. The response resulted in the characterization and formal documentation of a model of management for a fleet of nuclear plants. The operating model was born.

In 2000, the company did indeed merge with another fleet of nuclear plants. Rigorous deployment of its formal management model across the two organisations yielded immediate performance gains. More importantly, over the ensuing two decades, every plant in the expanded fleet demonstrated consistent and superior performance results and assessment ratings. A combination of well-defined <u>governance</u> standards, relentless <u>oversight</u> techniques, tremendous levels of corporate and plant-to-plant <u>support</u>, and rising levels of individual accountability for <u>performance</u> - all formally documented and adhered to - became a proven approach to exemplary nuclear plant and fleet operation.*

The key point you should take away from this industry experience is that the rigorous development and disciplined execution of a robust operating model is a proven approach to achieving superior and sustainable performance results. Its use is both valuable and validated. Building and implementing an operating model is your answer to stakeholders when asked: “How will you meet project expectations for plant operating performance?”

*Note: The words underlined above constitute the acronym G.O.S.P. This acronym is one of the underlying principles of execution employed with a management model. Some organisations use the alternate acronym G.O.E.S for Governance, Oversight, Execution, and Support. The word ‘execute’ is equivalent to the word ‘perform.’

So, what is an operating model?

The industry uses a variety of terms when discussing a formal operating model. Characterizations include a ‘playbook,’ a ‘management system,’ a National Quality Assurance (NQA) requirement… all are correct though each is incomplete to a degree. For our purposes, we will describe an operating model as a comprehensive, clearly defined, formally documented blueprint for “how an organisation does business.” The operating model applies to the entirety of the organisation, to include both corporate and operational functions and all supporting entities and stakeholders.

An operating model will define and document six major components that constitute your nuclear program:

1. People: The Organisation Structure and Staffing
2. Safety Culture
3. Policies, Programs and Processes
4. Administrative and IT Architecture and Infrastructure
5. Plant and Supporting Facilities and Equipment
6. Stakeholders

All aspects of each of the above should both integrate and complement each other.

Additionally, when properly maintained, an operating model serves as the basis for organisational knowledge retention. Examples like detailed program guidance; clearly defined, rule-based operating procedures; libraries of pre-job briefs; comprehensive maintenance work instructions; and training lesson plans, all serve to retain valuable plant and organisation information and lessons. Thus, an organisation becomes more resilient and less reliant on any one person or demographic. Your operating model forms a foundation for sustainable performance.[5]

How does an operating model work?

The components of your operating model, as described and documented, are intended to work in unison as an integrated system. Your model becomes the basis for day-to-day activity, personnel behaviours, and decision-making by your organisation. Your operating model comes alive when rigorously executed.

Performance by your plant and your people will be a direct function of three things:

1. How well individual components are defined.

[5] Application of the Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-G-3.1, 2006, and, the Management System for Nuclear Installations, IAEA Safety Standards Series No. GS-G-3.5, 2009.

2. How well all the detailed pieces integrate and complement each other.
3. How rigorously the organisation executes the model as written.

With regard to number three, underlying both the usefulness and effectiveness of your operating model is an executive expectation and organisational commitment to the rigorous execution the operating model as written. Said differently, the organisation must be accountable for procedural adherence – an underlying principle of strong nuclear operations. When your operating model is rigorously executed as written, two important things happen. First, sustainable operation with consistent results can occur. Second, a basis for performance observation, assessment and subsequent improvement activity can be established. From this basis, processes of continuous improvement can yield insights and identify opportunities that, when implemented and formally revised within your model, will serve to improve all aspects of your plant and organisation's performance. Your operating model and your performance will continually grow stronger. Failure by your organisation to execute the operating model as written will render it useless (i.e. documents on a shelf).

What is the risk of not having a well-executed, formal operating model?

The reality is every organisation has an operating model – how it behaves, how it makes decisions, how it executes core processes, etc. Seldom is it fully described and documented in a quality manner. For such organisations, the operating model can be said to be informal. Regardless of level of formality, it is being executed daily…or soon will be for new nuclear organisations.

The truth is an organisation's performance never stands still. Operational and organisational entropy, in all its various forms, is conspiring against you at all times. Plant components wear, organisational knowledge decays, the lessons of history are forgotten, and levels of passion for performance subside. Without compensatory actions, plant and organisational performance will decline. Entropy is constantly eroding your margins to success, and ultimately to safe plant operation.

Organisations with informal operating models are vulnerable. In such organisations, the consistency of employee activity and operational performance is primarily dependent on two things: 1) the effectiveness of the current leadership team, and 2) the extent of organisational knowledge and skill retention i.e. organisational memory. By way of example, in the absence of a strong operating model, a change in leadership – new personalities, new leader behaviours, and new directions - can more readily result in organisational dysfunction. Likewise, an employee demographic shift introduced by an early retirement program can create a loss of knowledge and skills that results in declining plant performance. In plants with informal operating models, sustainable performance can be left to chance; they are more vulnerable to the forces of cyclical performance.

An operating model helps defend the entropic forces that can erode operational and organisational margins. Rigorous daily execution coupled with constant organisational oversight, assessment, and reinforcement to defined operating standards and performance expectations will provide a comprehensive and systematic defence against such forces. The higher and more complete your level of compensatory activity is, the more effective and sustainable your operation will be. A detailed and documented operating model whose components are integrated and complimentary and whose day-to-day execution is constantly reinforced will sustain and grow operational performance and prohibit performance decline.

A new nuclear program has no operating model. But it soon will. From day one, performance standards, processes, employee behaviours and cultural norms will begin to form and evolve. As organisational and operational needs arise, something will rush in to full each void – the question you face is "What?" Every day your nuclear program progresses toward some end state. It is your obligation to define what your operation will look like and when. The next question for you is, how might you best influence that outcome?[6]

How do you approach building your operating model?

To commence building the operating model that is right for you and your organisation, thoughtfully answer the following eight questions. Keep in mind that very little of your operating model will be unique to the industry. There are existing industry examples, both good and bad, of virtually everything you do. You are encouraged to identify, access and use benchmarked content.

- Who is your chief architect(s)?*
- What more detailed operating model guidance is available?** Which will you use?
- What local regulations and international standards does your model need to embrace?
- What will your model structure look like?
- How will you approach content development?
- What are the readily available sources of nuclear program content?
- Can benchmark material be accessed or purchased?
- How can benchmarked material best be used? How will targeted content be adopted and adapted for local use?
- Is there any element of your model that is unique from all existing industry experience and must therefore be of original design and development?
- What is your administrative foundation both now and later?
- What is your nuclear operating language?
- What is your document standard (i.e. writer's guide)?
- What is your document hierarchy, structure and numbering scheme?
- What is your document draft and approval process?
- What is your approach to document retention and management?
- What is your IT foundation?
- What is your final IT global infrastructure tool?
- What additional tie-in modules will be targeted?
- How will you review and approve your model? How will your operating model evolve over time?
- Which stakeholders need to embrace your model?

*Definition: Chief Architect – person responsible for the design and development of the model. He/she has the authority to integrate evolving parts of the model and resolve content conflicts.

[6] Nuclear Baseline and the Management of Organisational Change Good Practice Guide, NI

Person should be selected based on significant experience with model content and the historical evolution of its construction and use. His/her authority and direction are subject to CEO or CNO override.

**See guidance found within IAEA safety standards and publications regarding development of an Integrated Management System (multiple)

All the elements of your operating model are bound by the four principles underlined in the earlier section. The terms Governance, Oversight, Support and Perform are often combined in the simple acronym G.O.S.P. The proper application of this principle in the creation, implementation and use of your operating model and the supporting organisation can yield improved efficiency and effectiveness. (A word of caution: Many persons profess familiarity with the G.O.S.P. principle, but most have little to no practical experience in its use. Misapplication of this concept can and has yielded odd organisational alignments and resulted in employee confusion and less than effective and efficient execution. The message here, like in all things: be sure to get sound counsel.)

Defining the Key Elements of Your Operating Model

Your operating model will need to describe in detail the component areas cited above. This document will not endeavour to define a complete operating model; however, we do provide you a list of essential elements to consider for inclusion during the process of defining your operating model – your end state.

Your operating model will build on the vision and mission you establish for your nuclear organisation. Hopefully, terms like safe and efficient plant operation, sustainable operation, reliability, nuclear professionalism and excellence will be incorporated into your vision and mission statements.

The definition of your operating model should include descriptions for each of the following elements:

- Business Vision and Mission
- Organisational Functions*
- Values and Behaviours
- Essential Policies
- Required Processes*
- Required Programs*
- Essential Documents*
- Critical stakeholders

*A listing of recommended content for these elements can be found in Appendix 2.

Establishing a Strong Foundation for Nuclear Safety

Your operating model will be the foundation upon which you will build a strong nuclear program. This section will endeavour to provide insight into those elements and attributes of your operating model deemed essential to helping you build a healthy safety culture and achieve a safe, efficient, event-free operational result.

As a prospective new owner and operator of nuclear power plants, nuclear safety must become your overriding priority. Doing so means adopting a philosophy of conservatism in decision-making. Doing so also means adopting behaviours aligned to the highest standards of nuclear professionalism and safe plant operation.

So, what are the dimensions of safety for our nuclear program?

A Healthy Safety Culture has been defined as an organisation's values and behaviours – modelled by its leaders and internalized by its people – that serve to make safety your highest priority and nuclear safety your overriding priority. Safety for your nuclear power program can be broken down into the following five key areas of safe and secure plant operation.

- Nuclear Safety – protecting the integrity of the reactor and its core of nuclear fuel before, during and after plant operation. <u>This is your overriding priority.</u>
- Radiation Safety – protecting plant and public personnel and the environment from the potential negative effects of ionizing radiation emanating from radiation fields and contamination sources generated during plant operation.
- Industrial Safety – protecting personnel life and limb while conducting plant operation, maintenance and support tasks within the industrial environment of your plant and site.
- Environmental Safety – protecting the environment from uncontrolled and excessive release of airborne, liquid and physical material originating from any and all aspects of nuclear plant operation. Such releases also include thermal releases to discharge waterways.
- **Security** – controlling and protecting reactor fuel and major nuclear plant components during all phases of plant procurement, construction, commissioning, operation, and decommissioning from any and all internal and external threats.

The definitions above will be characterized slightly differently by some. The benefit of the above is simplicity and clarity. Importantly, the definition reinforces the importance of leader and worker behaviours.

Safety is broken into five component parts. While each of the five components is different, they are all linked by common values, principles, behaviours and programmatic approaches. Concepts like personal accountability, protecting safety margins, conservative decision-making, human error reduction and more have applicability to each of the five areas of safety. Organisational weakness in any of these common traits will create risk in all safety areas. When pursued correctly, these common traits will help build a healthy safety culture and strengthen performance in all five safety areas.[7]

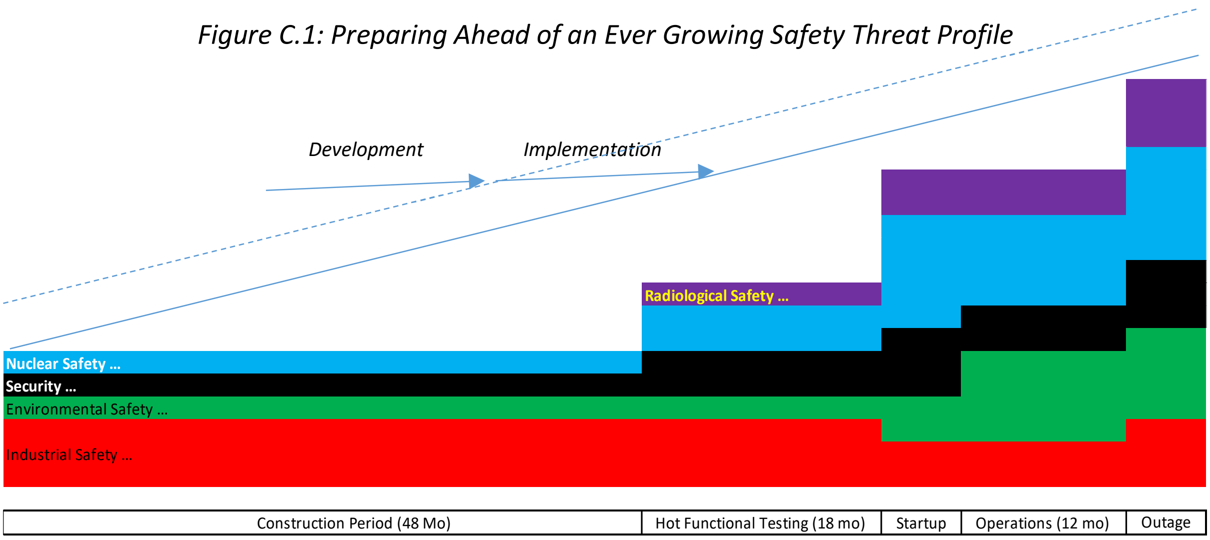
[7] WANO PL 2013-1 - Traits of a Healthy Nuclear Safety Culture

How will you prepare your organisation to behave safely?

Safety risks rise as your plant, organisation, and the level of operational activity grows and evolves. Very early on, your safety concerns will be largely limited to the minor aspects of industrial safety related to an office environment. As time passes, site environmental and security concerns will grow as site work begins. As the plant is built, the scope and complexity of industrial safety concerns will rise dramatically. Nuclear safety risk profile becomes increasingly relevant as commissioning commences. Finally, radiation safety grows from the receipt of fuel and increases exponentially with first criticality. As your safety risk profile rises, so does the challenge to your plant, program and people. The key leadership challenge is to prepare your organisation in advance to meet these challenges.

Thus, your key challenge will be to build a healthy safety culture – policies, programs, personnel mind set, behaviours, etc. – and do so well ahead of the growing threat that plant construction, testing and operation present. Targeted programs and processes must be well developed and rigorously implemented, and associated behavioural expectations must be defined, practiced and constantly reinforced ahead of the threat. The escalating safety challenge you will face as your project progresses is depicted here:

Figure C.1: Preparing Ahead of an Ever Growing Safety Threat Profile



Source: New Unit Assistance Working Group

Our message to you: commence building your safety culture on day one.

What values must an organisation embrace to establish a healthy nuclear safety culture?

Your operating model must define your organisation's core values. While the defined values from one organisation to the next will vary based on circumstances and culture, the following four values are considered essential to building a safety culture:

1. Safety First – a commitment to prioritizing safety above all else.
2. Personal Accountability – the commitment by every employee to embrace their responsibility for nuclear safety and to accept both the obligations and consequences of doing so.
3. Integrity – a realization that a safe plant and program can only be achieved by managing with facts i.e. the truth. Individuals must be honest in all matters to include reporting and test taking. They must do the right thing even when no one is watching.

4. Transparency – a recognition that the truth is without value if it is unknown. Disclosure both within the organisation and with industry colleagues is essential to safe operation.

Arguments can be made for the inclusion of other values that are critical to building a healthy safety culture. Examples of such include teamwork and continuous learning. But the above four values are a must. When properly defined values are regularly communicated and consistently modelled by leadership and embraced by employees and contractors, organisational trust is built. Trust, once earned and consistently maintained, can be leveraged into stronger operational and organisational performance.

So how and why do we include these safety concepts into our operating model?

Your operating model will include a great many elements, all of which will provide plant, program and organisational defence in depth. One important illustration of the defence in depth concept is pictured here:

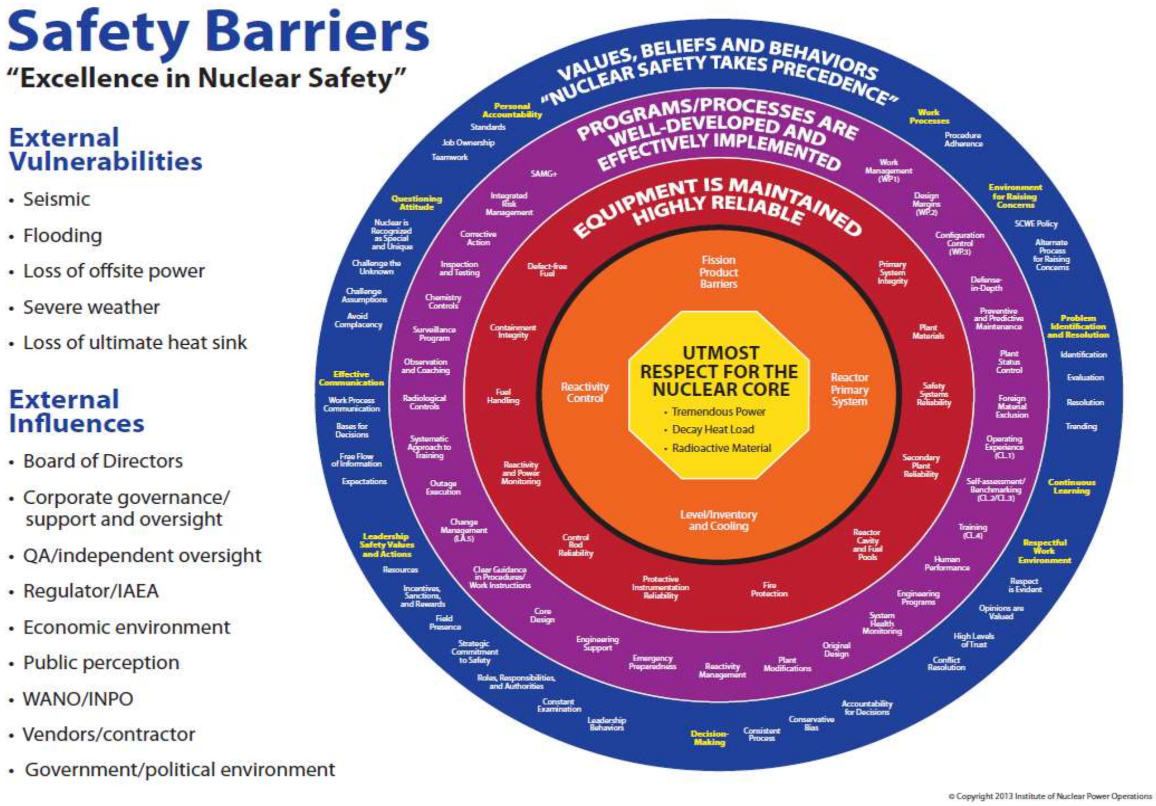


Figure C.2: Defence in Depth Safety Barriers

The concept of defence in depth suggests, and appropriately so, that strengthening each and every element of your plant, program and people reduces vulnerabilities and thus creates margin to events of all types. Doing so is thus foundational to building a healthy safety culture.

While every element of your operating model will strengthen your overall program and help create defence in depth, the following elements are arguably the most essential to building an operating model supportive of a strong and healthy safety culture:

- First, defining high and consistent standards of operational conduct across all functions, but critically the functions of operations, maintenance, engineering, chemistry, radiation protection and reactor engineering. These standards should include behavioural expectations for all employees.[8]

- Next, the development of a robust and high-quality licensed operator training and qualification program. This serves to staff the most critical position within the organisation – the main control room (MCR) operator staff. Doing so in the near term is essential to safe plant operation. In the long term, a strong operator training pipeline will provide the organisation a constant stream of persons with operational knowledge and capability, many of whom will dominate key leadership roles. Take note; operationally led organisations are proven to be the best performing nuclear organisations.

- Third, the incorporation of all recommendations specified within WANO's significant operating event reports (SOER) into your operating model. This mandatory action is designed to address and eliminate the operating risks exposed during our industry's history of significant events.

- Fourth, building a systematic approach to continuous improvement in pursuit of performance excellence. The supporting infrastructure must include the capability and sufficient capacity in the areas of issue identification, corrective action, operational experience, error prevention and assessment.

- Next, creating a capability to conduct effective event investigation and follow on analysis. Timely and thorough event investigation should lead to thoughtful analysis and the assignment of appropriate corrective action. These actions should include plant, program and people improvement actions to prevent event occurrence and the assignment of appropriate personnel consequences where necessary.

  A note: This capability is often underappreciated and under supported. Events will occur. They are always painful and often embarrassing. A mature leadership team, though, will see events as learning opportunities. When these events occur, failure to conduct timely and accurate investigations and take the appropriate actions will significantly undermine your program and damage your culture; successfully doing so will strengthen both.

  Additionally, the provision for the regular engagement of a quality and effective independent oversight capability. As envisioned here, this capability should be sponsored by the CEO and a company's board of directors. It should provide an important means of regular assessment, critical feedback, and operational guidance … and do so confidentially. This capability is not external assessment provided later by agencies like WANO/INPO[9] or the IAEA.

- Finally, and most importantly, a systematic approach to the growth and development of organisational leadership capability and capacity.

This last point deserves additional discussion. While the operating model your organisation defines is the foundation for your program and its future performance, the results it yields is directly dependent on the effectiveness of your leadership team. We will discuss this further in the section to follow.

Before leaving this section, a caution: Everything in this section assumes that licensed plant operators and the operating organisation have the authority to make decisions and take action to operate the plant safely. A corporate organisation must be respectful and supportive of the operator's responsibilities and licensed authority. It should be strong on support and cautious of

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[8] WANO Principle Doc PL 2013-01

[9] WANO GL 2018-01, Independent Oversight

actions which might undermine the authority of the operator. Corporate organisations must do no harm.[10]

Achieving Performance Results with Your Operating Model

You certainly have expectations for the performance of your nuclear program. You have or will shortly make commitments to a variety of stakeholders: safety obligations to your regulator, production commitments to the transmission system operator (i.e. the grid and grid operator), financial commitments to your shareholders, and aspirational commitments to yourself and your staff. Your challenge is how to execute your operating model to achieve desired levels of performance.

The ability of your nuclear program to produce, sustain and grow performance results is referred to as organisational effectiveness. Organisational effectiveness is a function of four things. First, the quality of your plant, your staff, your operating model, and your leadership team. The level of your program's performance is a function of your plant: how robust is the design, and how well was it constructed, and subsequently operated and maintained. As discussed in the previous section, the level of your program's performance is a function of your operating model: how complete is its scope, how detailed are its components, how understandable is its content, and how effectively and efficiently can it be executed. The level of your program's performance is a function of your people: how well staffed, trained and qualified are your people, and what is the collective capability and capacity of the nuclear professionals within (and supporting) your organisation. Lastly, and most importantly, the level of your program's performance is a function of the collective capability of your leadership team.

Your plant, your people, your operating model, and your leadership team work together to determine the effectiveness of your organisation and its performance results.

The following diagram illustrates how these four components work together to determine organisational effectiveness.

Source: WANO PCD 2019-01 Nuclear Leadership Effectiveness Attributes Leadership

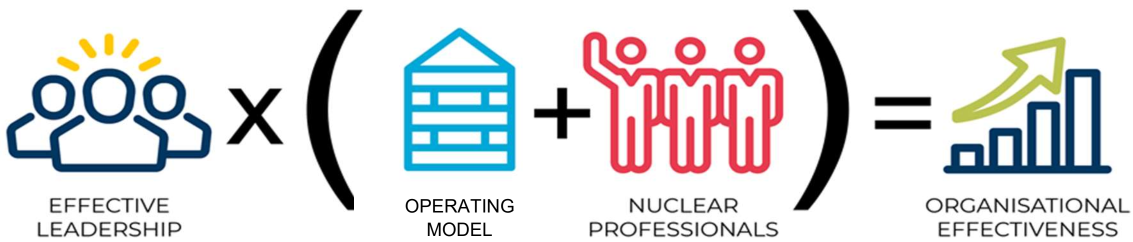


Figure C.3 Leadership Effectiveness Will Determine Your Results

Before we continue, note three things: First, as depicted, effective leadership – the capability and capacity of the leadership team - has a multiplying effect on organisational effectiveness. Thus, it is far and away the most significant factor in determining your operating performance.

Second, while effective leadership can compensate for a great many problems, poor quality of any one of the other three factors can and often does lead to significant events and undermines the strength and potential of the entirety of your program. Your program will fail if any one of these four factors is inadequate. Later attempts to correct an inadequate factor, if indeed possible, will be

[10] Safety Reports Series No. 74 - Safety Culture in Pre-Operational Phases Of Nuclear Power Plant Projects

extremely time consuming, costly and emotionally draining. Getting it right to start with will save time, money and tears.

Lastly, we want to recognize that the impact of a leadership team always lags in time (i.e. leadership team decisions and behaviours take time to manifest in either improved or declining performance). Depending on the issue(s), this lag can be anywhere from six months to 18. That said, strong nuclear operating programs that regularly post exemplary industry leading results are built and sustained by strong leadership teams. Conversely, nuclear programs in distress are seldom the blame of its plant, its operating model, and its people, but the lagging effect of poor leadership team effectiveness. The point is, plan to build, nurture and sustain a strong leadership team.

To close out the discussion on operating model, let us remind you of your obligation to lead your organisation. The question, of course, is lead them where? We strongly recommend you answer that question by building a high-quality operating model.[11]

[11] WANO PCD 2019-01 Nuclear Leadership Effectiveness Attributes Leadership and Management for Safety - IAEA Safety Standards Series No. GSR Part 2

Section D: The Journey to Operational Readiness

With an end state – your operating model – clearly defined, let us now turn to the journey required to develop, implement and satisfactorily execute all aspects of your operating model. As your operating model exercise has informed you, there is a tremendous amount of work to be done to prepare your organisation for safe plant operation. But now the question: what needs to be done when? You can develop, implement and execute the world's best operating model and still fail if the operating organisation is not ready at certain critical points of time.

With this in mind, this section endeavours to answer five key questions, namely:

1. What and when are the key milestones for success?
2. What level of organisational staffing is required to support plant operation?
3. What organisational capability needs to be created?
4. What does the scope and schedule of our operational readiness effort look like?
5. What state of readiness do we need to achieve at FCD? At HFT? And at FL?

This section is important for a number of reasons. First, the construction and commissioning experience can be a rich learning experience for the operating organisation. To take advantage of this opportunity, the operator needs to be in a posture of readiness when certain construction and commissioning activities demand. Second, failure to be ready for project critical path items can lead to project delays. The operating organisation must be ready to support key milestones in the construction and commissioning schedule. Delays to the project, and thus delays in generation and revenue, because of a lack of operator readiness will not be acceptable. Knowing when to be ready to provide high quality operational capability and capacity is critical to fulfilling your obligations.

Before answering these questions, let us first establish some terms critical to discussing the journey to operational readiness.

How will we define and discuss the phases of the project?

The journey to operational readiness runs parallel to the numerous activities involved in new plant contracting, construction and commissioning. Many construction and commissioning activities require significant operator interface, preparation and support. Our discussion here will benefit from the use of common terminology. To enable this discussion, we have worked to standardize program and project terminology using a broad variety of industry reference documents from such organizations as WANO and the IAEA.

New nuclear entrant countries will start and develop their nuclear program infrastructure and their first nuclear new build project with the benefit of guidance contained within a broad suite of IAEA documents. To begin, let us take a moment to differentiate between the terms nuclear program and nuclear project. The term program is used to refer to a country's supporting nuclear infrastructure. The term project is used to refer to a specific plant(s) new build. The model is: a country has a nuclear power program consisting of the national infrastructure elements required to provide essential support of one or more nuclear power plant projects hosted by one or more owner/operator entities.

The IAEA has outlined the development of 19 national infrastructure elements, referred to in documentation as issues. Each of these infrastructure issues are essential to the support of a new nuclear program and associated nuclear plant projects. The 19 issues are depicted as follows:

These 19 infrastructure issues are described in three phases. The three program phases are Phase 1: Considerations before a decision to launch a nuclear power program, Phase 2: Preparatory work for the contracting and construction of a nuclear power plant after a policy decision has been taken, and Phase 3: Activities to implement the first nuclear power plant. At the end of each phase is a program milestone. Program phase one is completed at Milestone 1: Ready to make a knowledgeable commitment to a nuclear power program. Program phase two is completed at Milestone 2: Ready to invite bids/negotiate a contract for the first nuclear power plant. Program phase three ends at Milestone 3: Ready to commission and operate the first nuclear power plant. This terminology is outlined in the following table:

Program Phase	IAEA Program Phase Title	IAEA Completion Milestone Title
1	Considerations before a decision to launch a nuclear power program	Ready to make a knowledgeable commitment to a nuclear power program
2	Preparatory work for the contracting and construction of a nuclear power plant after a policy decision has been taken	Ready to invite bids/negotiate a contract for the first nuclear power plant
3	Activities to implement the first nuclear power plant	Ready to commission and operate the first nuclear power plant

Table D. 1 IAEA Program and Milestone Nomenclature

The three phases and associated milestones are described in detail in the Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy Series NG-G-3.1 Rev. 1.

Our discussion of the journey to operational readiness will benefit from a more detailed breakdown of the phases and milestones required for the completion of a new nuclear plant project. Your understanding of the discussion that follows will be aided by the depiction provided in figure D.1 included in the pages that follow.

What are the key project phases?

With the benefit of this guidance, we have defined five phases to support our analysis and subsequent discussion. The five phases are 1. Program Pre-Feasibility Study, 2. Project Feasibility Study, 3. Project Commercial Contracting, 4. Plant Construction and Commissioning, and 5. Plant Commercial Operation.

The five phases are defined as follows:

1. Program Pre-feasibility Study – the period of time from the start of new nuclear program consideration and evaluation to the point of declaring real and/or planned national support for a nuclear program. The period includes data gathering and analysis tied to the 19 key infrastructure issues defined in the IAEA document entitled Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy Series NG-G-3.1 Rev. 1. Examples include strategic evaluations of a country's natural environment, industrial base and human capital capability and capacity. This period typically results in a formal government decision to either approve (or reject) the development and funding of a country's comprehensive nuclear infrastructure and support for subsequent plant projects. An approval decision is captured in nuclear law and some statement of policy outlining a country's commitment to principles.

   This is program phase one as defined by the IAEA. It concludes at Milestone 1: Ready to make a knowledgeable commitment to a nuclear power program.

2. Project Feasibility Study – the period of time from the start of new nuclear power plant project consideration to plant project approval to proceed. During this period a specific site(s) is (are) qualified and selected, a plant technology is presumed, and a supporting financial analysis is conducted. Critical regulatory tasks during this period include the preparation and submission of a site evaluation report and an environmental impact assessment. A critical commercial task during this period is the determination and creation of new plant specifications. These specifications form the technical and commercial basis for a bid by potential vendor(s). Successful completion of this period includes regulatory support to proceed and a statement of desire by a company (or government entity) to initiate a nuclear plant project. This phase often includes significant discussions of strategic partnerships and alliances in support of national ambitions. This is especially true of new nuclear entrant countries.

   This is program phase two as defined by the IAEA. It concludes at Milestone 2: Ready to invite bids/negotiate a contract for the first nuclear power plant. The following phase will commence the start of program phase three as defined by the IAEA.[12]

3. Project Commercial Contracting – the period of time from a company or government's stated support to invest in a nuclear plant project to the placement of first safety-related concrete. Relevant activities include project bid solicitation, vendor consideration and selection, and the formulation and agreement of commercial and contractual terms. The phase includes plant design work by the selected vendor to include preparation of the Preliminary Safety Analysis Report (PSAR). The PSAR and comprehensive suite of supporting documents are, once carefully scrutinized and approved by the owner/operator, submitted to the regulators. This phase ends with the placement of first safety-related concrete.

[12] Preparation of a Feasibility Study for New Nuclear Power Projects, IAEA NE Series No. NG-T-3.3, 2014

For supporting guidance in this analysis and decision-making, reference: IAEA Nuclear Contracting Toolkit, 2016

During this period of time, operational decision-making begins to be critical. Your organisation should begin to hire and/or engage qualified and experienced operations personnel to help in project decision-making.

4. Plant Construction and Commissioning - the period of time from the placement of first safety-related concrete to the completion of satisfactory testing of all plant component and system functional testing. This period ends at the commencement of plant commercial operation.

   Construction activities include the placement and/or erection of plant physical infrastructure, the installation of major plant components, and the connection of plant components and systems. The majority of construction activities conclude with the satisfactory turnover of all plant areas and systems to the commissioning organisation and subsequently to plant operations. The balance of construction activities will include the completion of punch list items from plant system and area turnover efforts, and the corrective actions (e.g. repair and/or plant design changes) required to achieve successful commissioning test results.

   As construction activities for various plant systems and areas end, commissioning begins. As defined by the IAEA, this transition from construction to commissioning signals the completion of program phase three and achievement of Milestone 3: Ready to commission and operate the first nuclear power plant.

   Commissioning activities include three key testing periods: A. Cold Functional Testing (CFT), B. Hot Functional Testing (HFT), and C. Power Ascension Testing (PAT). These three test periods are defined as follows:

   A. Cold Functional Testing (CFT) - The testing of plant components and systems at less than plant design rated temperature. The scope of this testing typically includes the following:

      i. Cold Hydrostatic Pressure Test (CHT) of the <u>Primary</u> Reactor Coolant system – the pressurization of the primary system to verify system integrity. This test requires the turnover to the commissioning organisation of all systems required for CHT.

      i. Cold Hydrostatic Pressure Test (SHT) of the <u>Secondary</u> side systems - the pressurization of the secondary system to verify system integrity. This test requires the turnover to the commissioning organisation of all systems required for SHT.

      ii. Local Leak Rate Testing (LLRT)

      iii. Containment Integrated Leak Rate Testing (ILRT)

      Other non-testing activities during this period of time includes the energization of the plant's auxiliary transformer.

      CFT activities are enabled by the process of system turnover from the construction organisation to the commissioning organisation, referred to as System Turnover for Blocking (TOB).

   B. Hot Functional Testing (HFT) - The testing of plant components and systems at plant design rated pressures and temperatures. Plant temperature and pressure requirements are met without nuclear heat. The scope of this testing includes the plant components and systems of both the primary and secondary systems (e.g. includes the run of turbine/generator at full rated speed). This period requires turnover to commissioning of all systems required for HFT.

Important to our discussion of operational readiness, the start of HFT necessitates our readiness to staff the Main Control Room (and the field) with trained and qualified operations personnel to support HFT activities. HFT is a critical opportunity for engineering, maintenance and operating staff (both inside and outside the main control room) to offer project support and, most importantly, begin the hands-on experience of learning how to operate the plant. All plant spaces and components will never be more accessible to the operator. In support of this, role clarity is particularly important. Roles and responsibilities must be clearly defined for all personnel controlled by the owner, the operator and the EPC contractor. Allowances for embedding operations personnel and defining the extent of their authority and participation during critical evolutions is very important. The roadmap targets full and active participation by the operations organisation during HFT and beyond. As we will soon discuss, taking advantage of this period of time will be the basis for the operations organisation's critical path schedule to the start of HFT.

Other important non-testing activities typically occurring during this period of time (or potentially just prior to in the case of plant control point) include the following:

- Plant Control Point (PCP) – the point at which the plant is in the control of the operator organisation to include implementation and use of all processes, programs and procedures required for plant status control.
- Plant Design Freeze (PDF) – the point at which any and all additional plant modification is placed on hold to allow 1) an update to all aspects of plant physical configuration documentation, and 2) the preparation and delivery of plant operator plant design change delta training.
- Fuel Receipt (FR) - the delivery, receipt and storage of all reactor fuel required for unit fuel load.

HFT activities are enabled by the process of system turnover from the commissioning organisation to the operations organisation, referred to as System Turnover for Testing and Operations (TOTO).

C. Power Ascension Testing (PAT) - The integrated testing of all plant components and systems at plant design rated pressure and temperature. Plant temperature and pressure requirements are met with the use of nuclear heat generated by the reactor.

The scope of important testing during PAT includes reactor physics testing and plant transient testing. This period of testing is extremely challenging and requires intense and singular organisational focus on safe plant operation and adherence to the highest operational standards and tenants of safe nuclear plant operation.

Important non-testing activities during this period of time include the following:

- Fuel Load (FL) – the initial loading of nuclear fuel into the reactor.
- Plant Startup (SU) – the initial plant startup to include initial reactor criticality and subsequent reactor power ascension.

- Initial Criticality – the first occasion of taking the reactor critical. This event initiates the long-term decay of nuclear fuel (and the generation of radiation and its by-products) and the creation of decay heat and the thus the need for shutdown cooling.
- First Grid Connection (FGC) - the moment at which the output breaker is successfully closed, and the generator is synchronized to the transmission grid for the first time.
- Warranty Outage (WO) – a short period of plant outage prior to commercial operation. This outage is typically the responsibility of the EPC contractor. It is conducted to remove temporary plant surveillance and testing equipment and conduct necessary post-PAT warranty maintenance.

During the commissioning time period, systems and components in operation will need surveillance and the appropriate level of preventive and corrective maintenance. Depending on the duration of time between HFT and the commencement of FL and PAT, systems and components not placed in service at the completion of testing may require a formal layup and preservation effort supported by chemistry, engineering, maintenance and operations.[13]

5. Plant Commercial Operation - the period of long-term plant operation that commences with the successful completion of PAT and the subsequent tie to the transmission grid to begin electric system generation and the receipt of commercial revenue. We refer to this point in time as the plant's Commercial Operation Date (COD). The scope of our discussions on operational readiness include preparation for the first cycle of operation and the first refuelling/maintenance outage.

   A. First Cycle of Operation (FOC) – the period of time from the start of commercial operation to the start of the first planned and scheduled plant shutdown in support of plant maintenance and/or refuelling. For PWR and BWR plants, the first cycle of operation is typically shorter than a normal cycle of operation due to initial reactor fuel burn management considerations. This period is typically around 12 months. In other plant types, e.g. PHWR and HTGR, this period is typically 24 months.

   B. First Refuel/Maintenance Outage (R/MO) – a planned period of plant shutdown. This period will include plant equipment repairs, plant inspections, surveillance testing, and implementation of plant modifications, and, for PWR and PWR plants, the addition of reactor fuel.

   For PWR and BWR plants, the outage critical path will typically be the shutdown, cooldown and refuelling of the reactor following by plant preparation for startup. For all reactor types, the outage scope will include testing and maintenance activities. This first outage will include a large scope of initial regulatory and equipment reliability testing and inspection. This first outage typically ranges in duration from 20 to 40 days (average 30), dependent on outage scope and organisational proficiency in the outage execution.

What are the key milestones across these phases?

The five phases encompass a number of important milestones critical to our discussion. These milestones are:

- EPC Contract Date (ECD) – the date on which the host country or project owner signs the Engineering, Procurement and Construction (EPC) contract with the chosen contractor. Per the roadmap guidance, the day should coincide with the formal existence of the operating

[13] Commissioning Guidelines for Nuclear Power Plants, IAEA NE Series No. NP-T-2.10, 2018, Mainly for Phase 3

organisation and thus the beginning of preparation for plant operation. This date is targeted as two years prior to FCD.

- First Concrete (Safety-Related) Date (FCD) - the date on which the first placement of safety-related concrete for the base mat of the reactor building occurs.
- Start of Hot Functional Testing (HFT) – the commencement of HFT and the necessity for operational plant staffing in support of all associated activities.
- Fuel Load (FL) - initial loading of nuclear fuel into the reactor.
- First Connection to the Grid (FCG) - the moment of time at which the output breaker is successfully closed, and the generator is synchronized to the transmission grid.
- Commercial Operation Date (COD) – the point of time after the successful completion of PAT and execution of an as needed warranty outage, when the generator breaker is connected to the electric transmission grid and electricity is provided in pursuit of commercial revenue.

The phases and milestones defined above are depicted in figure D.1 that follows.

The scope and complexity of operational readiness preparations activities is significant. Not only is the degree of difficulty high, but the quality standard for preparation of each is extremely high. Most importantly, achieving operational readiness for fuel load will require significant regulatory scrutiny and approval, as well as the conduct of satisfactory external assessments by WANO and the IAEA (if requested).

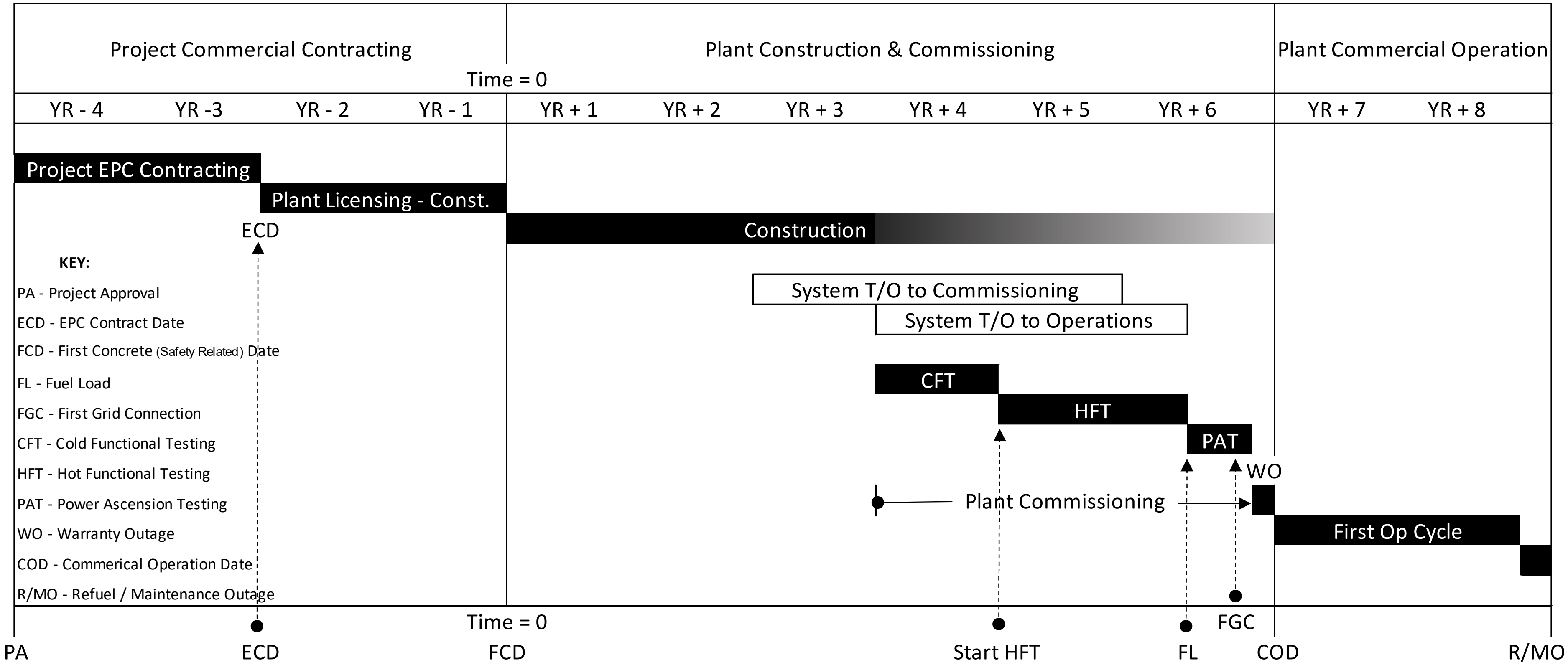


Figure D.1: Standardized Sequence of Project Activities to Plant Operation

Source: New Unit Assistance Working Group

Time Table for Operational Readiness

How long do we have to plan and prepare for each key project milestone?

Before answering this question as it pertains to your project, let us first discuss the question as it pertains to the development of your country's nuclear program. To begin this discussion we once again reference the guidance contained within IAEA document NG-G-3.1 Milestones in the Development of a National Infrastructure for Nuclear Power. This guidance suggests that the expected time for a new entrant nuclear company to complete program phases 1, 2 and 3 is about 15 years. Allowing for unusual circumstances, the Program Pre-Feasibility Study Phase 1 can take one to three years, the Project Feasibility Study Phase 2 three to seven years, and Plant Construction and Commissioning Phase 3 seven to ten years. This timetable has been largely borne out by the most recent UAE experience - at its start, the first new nuclear entrant country in thirty years.

For our purposes, we need to focus on the duration of the key project phases. To help answer this question, your attention is directed to Appendix 3 of the roadmap. This appendix provides several illustrations of new unit planning timetables and actual industry construction project experience performance data.

Generally, your objective is to achieve operational readiness when the plant is ready to operate. To go a step further, your operating organisation must be ready in all respects to support each of the following key milestones 2 through 5 above. So, for planning purposes we must know how long we have to prepare. Summary analysis provided in the appendix yielded answers to the following four key questions:

1. Planning duration of time from FCD to Start of HFT?
2. Planning duration of time from FCD to FL?
3. Planning duration of time from FCD to First Grid Connection (FGC)?
4. Planning duration of time from FCD to the Start of the First Refuel Outage (RFO)?

The chart provides key summary data distilled from the three illustrations provided in Appendix 3. The chart data is shown in months

Source: New Unit Assistance Working Group

Questions A - D	A	B	C	D	
	HFT	FL	FGC	RFO **	Notes
Illustration # 1	42	48	51	63	Planning Basis
Illustration # 2			79 (72)	91	WW Actual (East Asia)
Illustration # 3 - Average	85	102	107	119	Actual / Projections
Illustration # 3 - Early	49	85	98	110	Actual / Projections
Planning Determination	48	66*	72	84	

Table D.2 Project Timing Planning Basis

Table Notes:

1. * Fuel Load determination based on the subtraction of a 6-month average duration taken from illustration #3 from the 72-month average duration to First Grid Connection. Six months is twice the defined planning duration.
2. ** The start of the first refuel / maintenance outage is calculated simply by adding an assumption for the duration of the first operating cycle. The FOC duration assumed in the table is 12 months.

Operations needs to be ready when the plant is ready. Not being ready means delaying plant operation and thus the start of generation and revenue. After a decade of significant effort and expenditure, the executive appetite to begin plant operations will be voracious. The pressure on the operator to commence fuel load, startup, and begin plant operation will be significant. Accordingly, the milestone timing assumptions (shown in table D.2) for satisfying the operational readiness criteria for fuel load (as outlined in figure D.6 ahead) are conservatively early.

What are the operational risks of not being ready to load fuel and begin plant operation?

The benefits of your project are numerous. With project delay comes a delay in the delivery of these benefits and correspondingly to a return on investment (ROI). For the operator, a project delay includes the following risks:

- The potential for plant component and material degradation.
- Pressure on the organisation, real and perceived, to commence operation. This pressure can encourage people to hurry and/or take shortcuts in preparation. In the near term, both can lead to errors and events. In the longer term, once encouraged, such undesirable operational behaviours will be hard to correct. This can be a significant impact on your efforts to build a healthy Nuclear Safety Culture and establish a foundation for long-term performance excellence.
- The loss of plant operating skills and knowledge if organisational frustrations and/or personnel career timings yield accelerated attrition.
- The removal of key operational leaders due to a failure to achieve on time operational readiness. Leadership changes during this critical phase of the project can have a significant impact on the safety culture, organisational focus, and thus safe plant startup and operation which is undesirable.

Are there benefits of the operating organisation being ready early?

The simple answer is YES. Early readiness can mean:

- Greater operational participation in testing and commissioning activities. Plant knowledge and experience gained by plant operating personnel engaged throughout these activities will be significant and result in safer, more efficient operations later.
- Earlier transition to plant processes, programs and use of operating procedures. Organisational process, program and procedural proficiency will grow as documents are used, assessed, and upgraded and personnel become more comfortable with their use.
- Earlier focus on changing plant personnel and contractor behaviours. Behaviour change is hard. Establishing desired behaviours early will improve safety and accelerate organisational efficiency gains.

- The use of operating organisation personnel as contingency in the event of contractual and commercial challenges.

There are numerous and significant benefits to being ready early. You should conservatively embrace the timing durations determined and outlined previously and summarized below.

One additional note: The early staffing of nuclear plant operations personnel long before plant startup will seem extremely unusual to non-nuclear executives. Short-sighted program executives may well lament the cost of operational staff long prior to operation. It is helpful to remind these executives of the revenue projected for each day of plant generation…and the projected losses incurred during delay. When related discussions occur, operational executives are well served to have a number for “revenue per day of plant generation” in their back pocket.

So, when should the operator be ready?

The journey to operational readiness should assume that from the placement of first safety-related concrete, the plant will be ready to conduct HFT in 48 months (4 years) and be ready to load fuel in 66 months (5.5 years). Similarly, the plant will connect to the grid in 72 months (6 years) and conduct its first refuel/maintenance outage 12 to 24 months later (84 to 96 months).

This journey is depicted in the simple diagram Figure D.2 that follows. The operator should incorporate these timings into their schedule, planning and preparation efforts toward operational readiness.

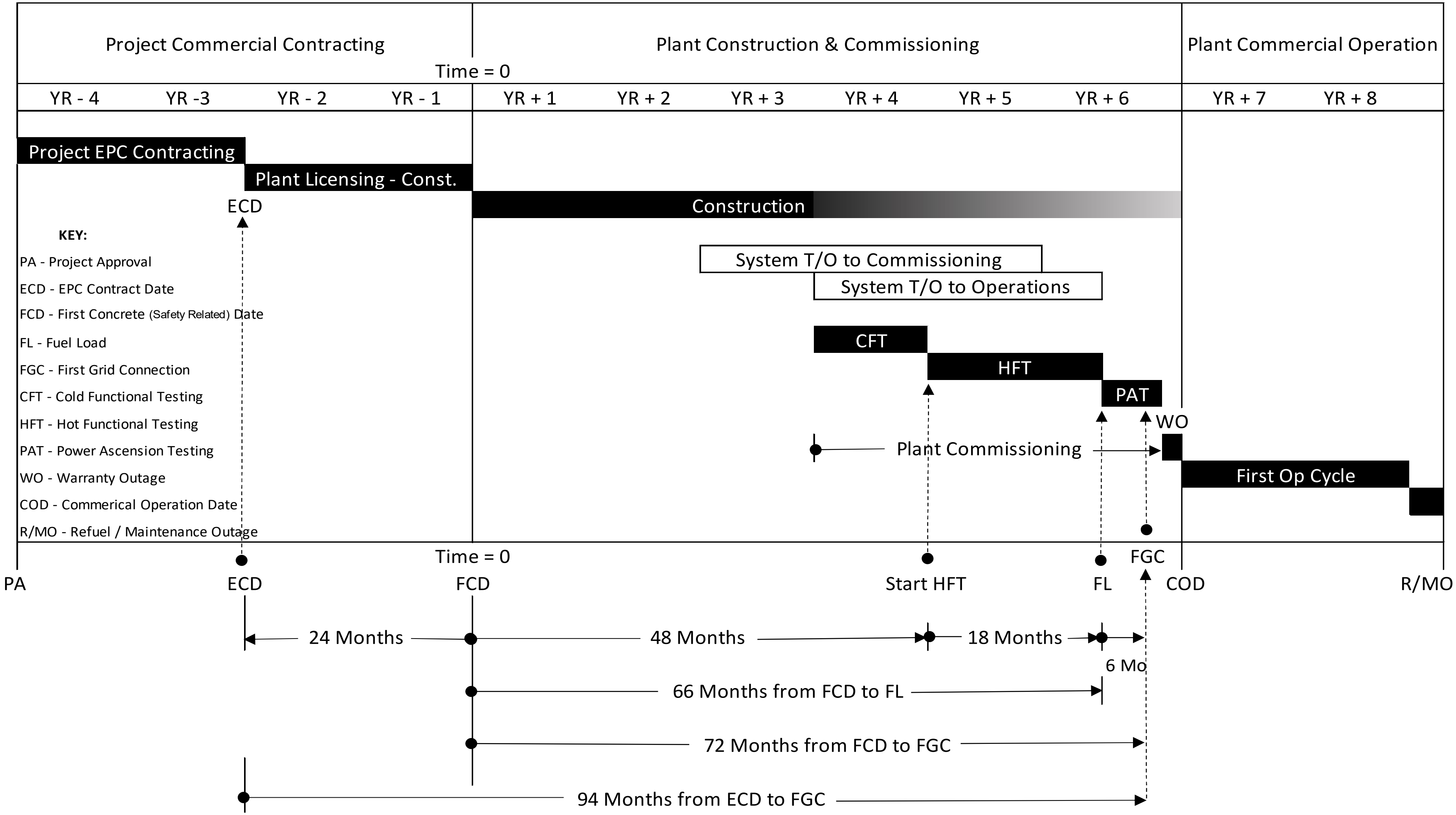


Figure D.2: Operational Readiness Planning Assumptions

Source: New Unit Assistance Working Group

What is our critical path to success?

To begin the conversation, let us first state that mismanagement of any activity required in support of one of our defined operational criteria for FL can become critical. That said, let us discuss ideally what should drive our critical path to operational readiness for both HFT and FL.

Critical path is defined as the shortest possible sequence of logically required events in support of an objective. If operations prepares properly, it should never be critical path. To avoid becoming critical path, operations must be ready for the milestones as discussed previously.

The Schedule Logic

1. Critical Path to the Start of Hot Functional Testing (HFT) Figure D.3
2. Critical Path to Obtaining an Operating License (FL) Figure D.5

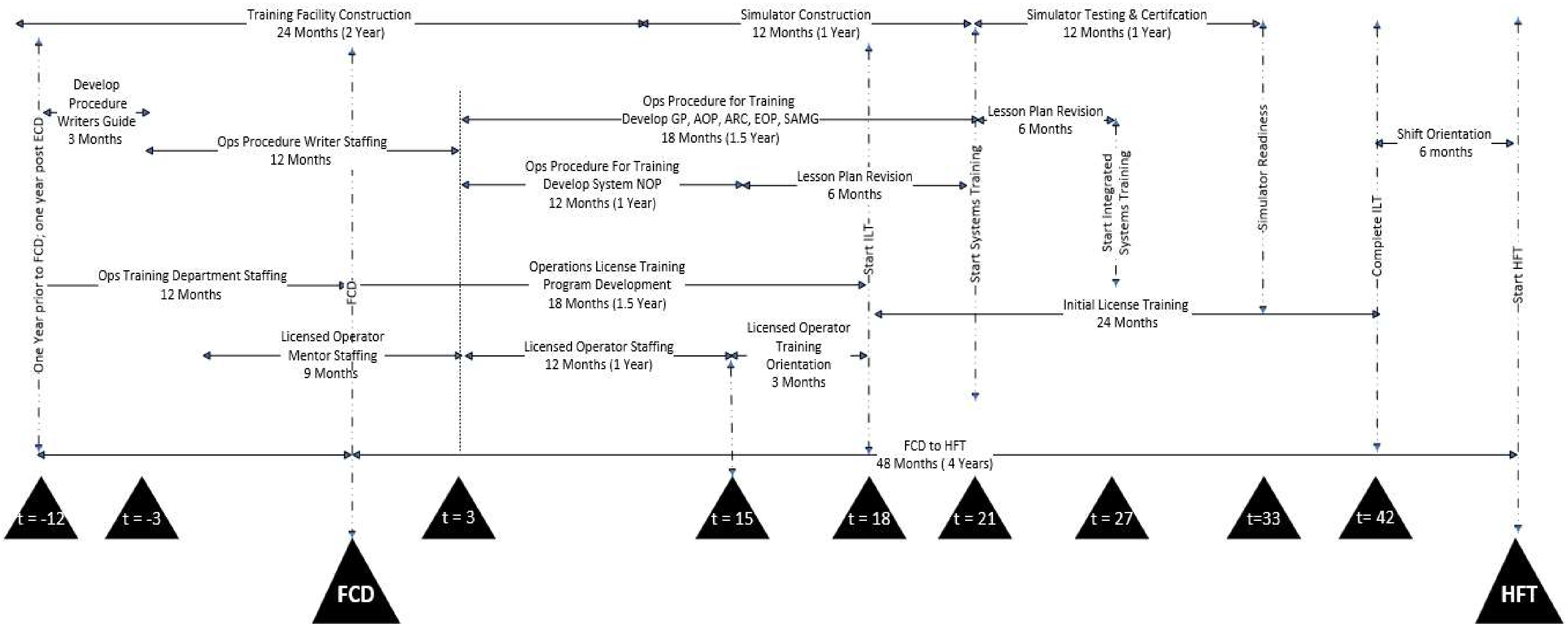


Figure D.3: Critical Path to the Start of Hot Functional Testing (HFT)

What does readiness for HFT look like?

Having defined the projected critical path schedules for achieving HFT, let us now present the prescribed readiness criteria to be achieved by the start of HFT:

Figure D.4 Operational Readiness Criteria for the Start of HFT

The following criteria should be met, and verified prior to the commencement of Hot Functional Testing (HFT) supported by Main Control Room (MCR) Shift Crews and plant field operators:

Plant:

- The satisfactory turnover of all plant systems required for HFT to defined commissioning standards
- The satisfactory turnover of all plant areas required for HFT to defined commissioning standards
- The completion of satisfactory construction testing for all requisite HFT plant systems

People:

- The staffing of operations main control room and plant operator staff personnel to targeted levels
- The training and qualification * of the requisite number of personnel for each organisational function
- The documentation and retention of all relevant personnel training and qualification records

Documentation:

- The development, implementation and functional verification of all processes and programs required for HFT
- The creation and implementation of mechanisms to capture, retain, and update plant design and testing documents and data
- The development, implementation and plant/simulator verification of all required plant operating procedures required for HFT
- The development and implementation of performance standards for the core functions of Operations, Chemistry Engineering, and Maintenance
- The development and implementation of NPI programs for CAP, HU and OE

Supporting Infrastructure:

- The implementation and functional verification of all underlying software infrastructure required for HFT
- The implementation and functional verification of all underlying document and record retention program
- The ability to collect, store and retain all critical plant data
- The availability of plant spares

Verification of Organisational Performance

- The formal assessment**of organisation readiness to perform HFT

Notes:

* Operations MCR personnel may be qualified but not yet certified by the regulator
* Unqualified personnel may perform plant functions with proper trainee oversight.
** This formal assessment is internal and can be led and performed by NO personnel

Source: New Unit Assistance Working Group

What does the follow-on critical path from HFT to FL look like?

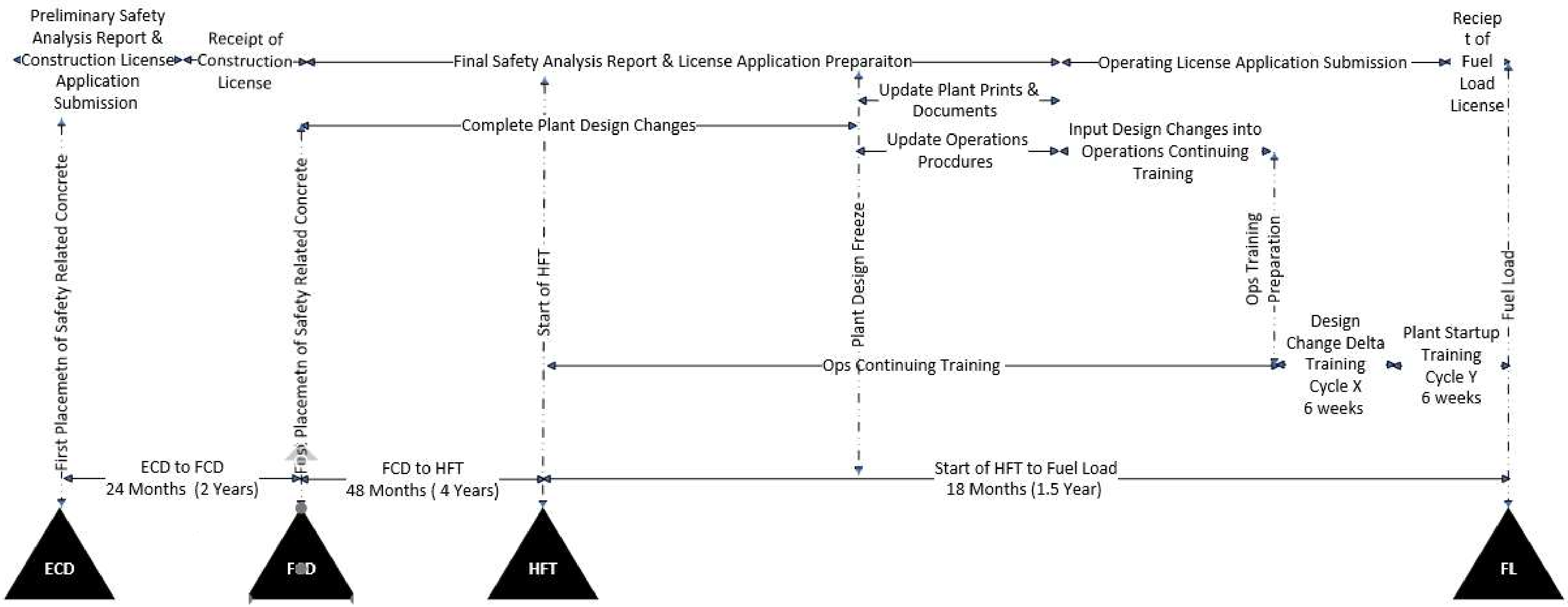


Figure D.5: Critical Path to Fuel Load (FL)

Having defined the projected critical path schedule for achieving FL, let us now present the prescribed readiness criteria to be achieved before loading fuel into the reactor:

Figure D.6 Operational Readiness Criteria

The following criteria should be met, and verified prior to Fuel Load in preparation for safe, full power reactor operation:

Plant Licensing:

- The submission of an Operating License application to the Regulator
- The receipt of an Operating License (or Licenses) from the Regulator
- The receipt of all required non-nuclear permits and licenses e.g. environmental, health & safety
- Satisfaction of transmission grid connection prerequisites and grid operator interface requirements

Plant:

- The satisfactory turnover of all plant areas and systems to defined operational standards. Includes receipt and verification of system design, component, vendor (e.g. Bill of Materials), and master data
- The satisfactory turnover of all plant areas to defined operational standards
- The completion of satisfactory* commissioning testing of all plant components and systems
- The verification of plant component and system line up in preparation for fuel loading
- The receipt and proper storage of new fuel
- As required, the satisfactory layup and preservation of commissioned systems

People:

- The assignment of an adequately experienced leadership team
- The staffing of personnel to defined organisational target levels for each functional area
- The training and qualification of the requisite number of personnel for each organisational function
- The documentation and retention of all personnel training and qualification records

Documentation:

- The development, implementation and functional verification of all processes and programs
- The development, implementation and plant/simulator verification of all plant operating procedures
- The development, implementation and verification of all plant procedures for each function

Supporting Infrastructure:

- The implementation and functional verification of all underlying software infrastructure
- The implementation and functional verification of an underlying document and record retention program
- The collection, storage and retention of all critical plant data
- The purchase, inventory, and warehousing of critical plant spare parts
- The completion and outfitting of all required facilities (to include support for outages)
- Complete and functioning security barriers and guard force capability

Verification of Organisational Performance

- The formal demonstration and verification of satisfactory operational and plant support task performance
- A demonstrated capability to conduct a safe plant shutdown and conduct a forced outage
- The completion of planned exercises and satisfactory demonstration of Emergency Planning Capability
- The successful completion of external pre startup assessments
- The verification of an adequate Nuclear Safety Culture and a demonstrated capability for continuous learning

Notes:

1) **Commissioning and startup testing needs to ultimately meet the operability criterion of the plant's technical specifications for each safety systems*
2) *The above criteria do not include that required for plant startup*
3) *Any exceptions to the above should be identified, formally captured, and evaluated individually and in aggregate. Justified and approved exceptions should be few. Approved exceptions should be tracked for near term completion*

Source: New Unit Assistance Working Group

What happens if our project is delayed?

There are many reasons that projects are delayed. The reasons experienced for such delays include the following:

- Unexpected design changes and equipment problems.
- Equipment, documents or data delivery, often complicated by commercial disputes.
- Additional design modifications incurred after industry accident and subsequent regulatory changes (e.g. after the 2011 Fukushima event, regulatory bodies established additional plant requirements for significant plant and program modifications.)
- Supply and installation of counterfeit plant components for safety-related equipment (e.g. the removal and replacement of safety system electric cabling caused a two-year delay.)
- Inability to resolve equipment performance technical issues in an effective or timely manner.
- Delays in operational staffing and readiness preparations due to lack of funding and/or executive support.
- Changes in governmental policies and priorities.
- Changes to corporate strategy and organisational configuration.

The potential for these delays is higher for new nuclear plant projects utilizing FOAK technology. As well, the potential for delay rises with the inexperience of the operating organisation. Unsurprisingly, new nuclear countries and companies are more vulnerable to delays than experienced entities.

While acknowledging the above, the impact to operational readiness is more opportunity than challenge. A savvy operator will benefit from a delay. Opportunities will be plentiful for operating organisation personnel to gain plant knowledge and experience while supporting construction and commission activities. Not to say there will be no issues of operational concern. A key example: delays can create long periods of equipment idleness. This will require the organisation to develop, implement and execute a preservation program to maintain various types of equipment in layup condition.

Building Organisational Capacity – Staffing

Like every organisation, people make the difference. Who you choose, how you train and qualify them, how you instil values and prompt desired behaviours, how you develop their operational skill sets, and how you sustain the motivation and commitment of your personnel over time will ultimately determine the success of your endeavour. So, what, how many, who and when should this be done to raise the probability of your success?[14]

How should you approach staffing the operations organisation?

You will have a great many questions to answer as you endeavour to define your staffing strategy and plan. A number of key questions follow:

1. What is the staffing model for your organisation?
    a. What is the basic organisational structure?
    b. What are your initially estimated staffing numbers?
    c. What is your plan for use of outsourcing (contracting)?
2. What are your staffing targets (percentages) for local hiring?
3. What is the current availability of potential employees with
    a. Nuclear experience?
    b. Non-nuclear experience with analogous industries e.g. oil and gas, aviation, etc.?
    c. No experience, but with targeted academic competencies?
4. What is the current availability of potential contracted support personnel?
5. Based on answers to questions 3 and 4, what is your need for capacity building (i.e. to what extent can local academic institution programs be adapted or created to create educational support)?
6. What special circumstances exist that warrant staffing consideration? Examples include:
    a. How remote is the site location?
    b. What is your core operating language and the level of local competency in chosen language?
7. How attractive* is your program to:
    a. Persons locally and from afar, be it internationally or otherwise?
    b. Both experienced and inexperienced personnel?

    *Note: At a minimum, a determination of the attractiveness of your employment opportunity should include a combination of all of the following: location, financial rewards, career development, living conditions, benefits and working hours.

[14] "Recruitment, Qualification and Training of Personnel for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.8," 2002

8. How and when can your country, community, organisation and site logistically support new hires (temporary and long term)?

Answers to the above questions are subject to local circumstances including such things as national aspirations, levels of available funding, and existing industrial infrastructure. While we will endeavour to answer many of the above questions, the answers are subject to your local conditions. It is hoped that the following discussions on staffing considerations will aide you in effectively answering local staffing questions.

What should your operating organisation look like?

Before we begin, this section discusses organisational structure required to fulfil operational responsibilities. While relevant to all points in time in the project, the discussion focuses on an end state, or at least the latter phases of your project. The operating organisation structure will necessarily start small and evolve and grow over the life of your project.

In addition to the operator role, the owner has additional roles to satisfy to include oversight of the construction entity, likely the EPC. This obligation for construction oversight is significant. To the extent the owner and operator roles (and potentially the construction role) are filled by the same entity, the organisational model, especially in early project phases, will vary. Decisions regarding organisational structure, resource sharing, and reporting relationships for licensing, quality assurance (QA) and engineering will need to be carefully considered with respect to organisational roles and contractual configuration. The design of your organisational structure for your operation will largely be a function of your defined operating model. The functions you designate and the processes and programs you define will largely dictate the scope of your organisational structure.

Let us now discuss a few important organisational design features you should adhere to when developing your operating organisation:

First, let us begin with a small, but important organisational detail. Consider entitling your lead nuclear operating executive as Chief Nuclear Operator (CNO). This will align readily with the majority of industry parlance, guidance and support.

Second, the number of levels within your organisation will vary, but your CEO should be able to look straight down through the operations organisation to the licensed operator at the controls of the reactor. This is depicted in figure D.7 in the right margin. In industry parlance, your CEO and CNO should have line of sight to the reactor core. This is an essential industry principle for safe nuclear plant operation.

Third, your organisational structure should align all core operating functions to your lead operations executive, the CNO position. These functions include operations, engineering, maintenance, chemistry, radiation protection and work management. This relationship is depicted in figure D.8 on the following page.

Finally, the Commissioning Oversight function is a temporary function that typically serves until the plant(s) achieve connection to the grid. This organisation should report to the operations organisation. Commissioning Oversight plays a key role in accepting systems from construction and verifying satisfactory testing of all systems and components. Commissioning Oversight

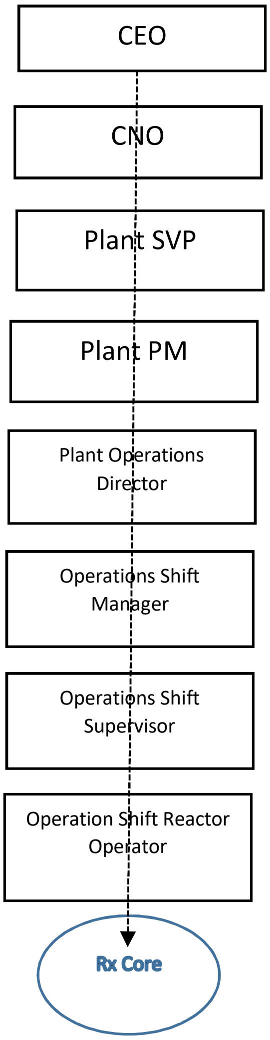


Figure D.7

is thus the organisation's first true guardian of operational standards. Its primary objective: delivery of a quality plant and facility. Alignment and teamwork with the core functions of engineering, maintenance, operations, etc. is essential.

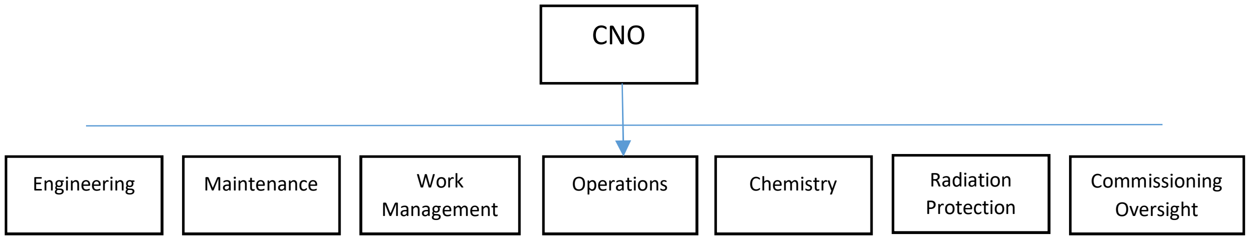


Figure D.8

Sources: New Unit Assistance Working Group

How many staff will the operating organisation need?

The required number of staff for every organisation will be different. Benchmarks across the industry vary. A single unit will typically have a higher per unit head count than a site with multiple units. Units with small generational output (800 MW) will have higher head count per megawatt than a unit with large megawatt output (1800 MW). Different technologies require some unique technical capability and capacities (e.g. heavy water handling and processing at CANDU facilities). For purposes of illustration, we will use a generic PWR staffing model.

Our organisational staffing model is based on a small operating nuclear corporation with one site hosting two reactor units. The model describes an organisation as it might exist near the end of its first cycle of operation. Our model and its staff numbers by function (and as appropriate by unit) is depicted on the following page. Our generic model has a targeted total staffing number of 1,250. This total may be considered conservatively high to some existing operators. This model is depicted in Figure D.9 that follows

Our model's total staffing number and functional distribution is approximately correct. Again, your numbers will vary. Even in the event your configuration is similar to the generic model, you are encouraged to engage industry experts in the field of nuclear plant staffing where bench mark information can inform the final design and size of your organisation. More detailed assumptions for our generic model are listed as follows:

Generic Two-Unit Organisation Staffing Model Assumptions:

- Normal plant operation post startup, testing and commissioning
- Non-outage staffing (i.e. no outage staffing included)
- Separate main control rooms for each of two units
- Six shifts of operators, chemists, radiation protection, security and fire protection personnel
- Work package planning located in work management
- Procedure writers embedded in respective disciplines
- No janitorial or decontamination staffing accounted for

- Minor, non-outage contracting support exists and not accounted for (e.g. water plant operation)
- No operator trainee pipeline for initial license training

There are a myriad of circumstances that can result in significant variability in these numbers. For example, human resource policy differences in leave allowance (i.e. two weeks versus six weeks) can suggest a need for 10% higher staffing. Additionally, the desire for a high degree of localization and the associated hiring of employees new to nuclear can drive numbers higher to accommodate the number of “trained, but not yet qualified” personnel in the pipeline and the need for additional support staff providing training and mentoring.

Why should initial staffing numbers be conservatively higher?

Employees cost money. Your operation will have a financial model for plant online operation it must eventually meet. Accordingly, there may be pressure to limit total staffing numbers and/or to delay staff hiring in the near term.

There is a positive safety benefit of conservatively high numbers in the form of contingency planning for unnatural organisational attrition. In part, the number helps account for the various sources of unnatural attrition which can occur post commissioning of the unit. Causes of higher than normal attrition post commissioning include an accelerated pace of ex-patriate return to home, loss of new nuclear employees disenchanted with the nuclear plant operating lifestyle, and any employee with a short term “declare victory and depart” mentality. As the operator, you must be prepared for just such an occurrence. Conservatively higher staffing numbers provide your operation built in contingency.

In the event attrition does not occur and pressure to reduce numbers is real, management has the opportunity to carefully screen employee performance and humanely remove low performing employees.

Caution: The worst-case scenario is an inability to operate your units and generate electricity and revenue due to an insufficient number of licensed operators. In such a scenario, the regulator will not allow you to operate. The time to recover sufficient number of licensed operators can be years.

Note: The staffing numbers in provided in Figure D.9 on the following page makes no allowance for an operator trainee pipeline in support of continued initial license training. Additional staffing of approximately 80 operator trainees will be required to maintain licensed staffing numbers for a two-unit site. This assumption licenses approximately 40 operators a year assuming a 100% pass rate. (Note: Differing industry approaches to license training and varied levels of training program performance yield a wide range of trainee qualification rates, from as low as 20% to as high as 95%. You will need to adjust your numbers accordingly.) You are encouraged to obtain an operator license pipeline software tools to more accurately manage trainee numbers in support of your specific operational aspirations.

Generic Two Unit Staffing Estimate

		Unit 1	Unit 2	Common	Function Total
1	Administration (Administrative Support)	6	6	16	28
2	Chemistry	18	18	10	46
3	Commissioning Oversight (Temporary)	-	-	-	-
4	Communications			6	6
5	Decommissioning			1	1
6	Document Control & Records Management	6	6	4	16
7	Emergency Preparedness			20	20
8	Engineering Senior Leadership			5	5
	a. Design Engineering			20	20
	b. System Engineering			40	40
	c. Engineering Other / Support			20	20
9	Environmental Management			10	10
10	Export Controls			4	4
11	Facilities Management / General Services			10	10
12	Finance			10	10
13	Fire Protection (includes Fire Response Team	24	24	10	58
14	Fuels			10	10
15	Health and Safety			10	10
16	Human Resources			30	30
17	Information Technology (IT)			30	30
18	Integrated Management System			1	1
19	Internal Audit (IA)			8	8
20	Legal			5	5
21	Licensing & Regulatory Affairs			10	10
22	Maintenance Senior Leadership			5	5
	a. Supervision			25	25
	b. Craft			120	120
	c. Maintenance Support			40	40
23	Management (Senior and Executive level)			10	10
24	Nuclear Oversight			6	6
25	Nuclear Performance Improvement (NPI)			15	15
26	Nuclear Risk Management			3	3
27	Operations Senior Leadership	4	4	2	10
	a. Main Control Room Staff - Shift	36	36		72
	b. Field Staff - Shift	36	36		72
	c. Operations Support Staff	4	4	28	36
28	Organizational Effectiveness (OR)			4	4
29	Plant Projects			10	10
30	Procurement & Supply Chain			50	50
31	Program Management			10	10
32	Quality Assurance			10	10
33	Radioactive Waste Management		6	4	10
34	Radiological Protection	12	12	16	40
35	Reactor Engineering			10	10
36	Safeguards			4	4
37	Security			20	20
	a. Security Officers			80	80
38	Training			100	100
39	Work Management			60	60
	a. Work Planning			30	30
	Totals				1250

Figure D.9 Estimated Staffing Numbers

Source: New Unit Assistance Working Group

What is your hiring priority?

To be successful, your hiring must support the critical path schedule, the timely development and implementation of all processes and programs, and the organisational capability to satisfy the criteria for each milestone.

With guidance for target numbers in hand, we will now begin to address the question of hiring sequence. We will answer this question by first breaking it down into four categories:

1. What is the hiring priority for the function?
2. What is your hiring priority by position?
3. What is your hiring priority by process?
4. What is your hiring priority by program?

Each question will be answered separately. They will be answered in the logical sequence suggested above. Once answered, the subsequent section will merge our answers for hiring priority with our answers for target staffing numbers to determine a staffing curve.

Again, your specific answers to every question asked throughout this section will vary. Your specific program answers will likely introduce only slight numerical variations. Some answers will add to totals and some will subtract, the total will be largely unaffected. Our final answers should be directionally correct and thus provide your program sound guidance.

What is your hiring priority by function?

Staffing of the organisation should follow the functional scheme as indicated in the following chart:

		Plant Licensing (ECD – FCD)	Construction (FCD – HFT)	
		YR - 2 YR - 1	YR + 1 YR + 2	YR + 3 YR + 4
		Priority 1	Priority 2	Priority 3
1	Administration (Administrative Support)	X		
2	Chemistry	X		
3	Commissioning Oversight (Temporary)		X	
4	Communications	X		
5	Decommissioning			X
6	Document Control & Records Management	X		
7	Emergency Preparedness		X	
8	Engineering	X		
9	Environmental Management	X		
10	Export Controls		X	
11	Facilities Management / General Services		X	
12	Finance	X		
13	Fire Protection (includes Fire Response Team)		X	
14	Fuels	X		
15	Health and Safety	X		
16	Human Resources	X		
17	Information Technology (IT)	X		
18	Integrated Management System	X		
19	Internal Audit (IA)		X	
20	Legal		X	
21	Licensing & Regulatory Affairs	X		
22	Maintenance		X	
23	Management (Senior and Executive level)	X		
24	Nuclear Oversight			X
25	Nuclear Performance Improvement (NPI)		X	
26	Nuclear Risk Management	X		
27	Operations	X		
28	Organizational Effectiveness (OR)		X	
29	Plant Projects			X
30	Procurement & Supply Chain	X		
31	Program Management	X		
32	Quality Assurance	X		
33	Radioactive Waste Management			X
34	Radiological Protection			X
35	Reactor Engineering			X
36	Safeguards		X	
37	Security		X	
38	Training	X		
39	Work Management			X

Figure D.10 Functional Hiring Priority Chart

Source: New Unit Assistance Working Group

What is your hiring priority by position?

To build your organisation in the most efficient and effective manner, the hiring priority and approximate hiring sequence by position type should look as follows:

- Executive leadership
- Functional area leadership/management
- Operations training personnel and instructors
- Operations mentors and management personnel
- Lead experts for each process and program
- Plant operator and chemistry staff
- All others

For the first five categories above, the majority of hires should be nuclear qualified and experienced personnel. This is true even in the non-nuclear core functions like HR, procurement, communications, etc.

Embedded in the first two categories above is the need to fill five important individual roles:

1. An operating model architect (See previous Section C.1)
2. A master scheduler (See Section D.4 to come)
3. An operating license project lead
4. An enterprise software systems application lead
5. A Significant Operating Experience Report (SOER) recommendation implementation project lead

The hiring of individuals to fill these critical positions should be accomplished with particularly careful scrutiny. Each individual selected should have significant nuclear experience, strong technical capability, keen project management skills, and appropriate leadership competencies.

It is recommended that the operating model architect report directly to the lead operations executive i.e. CNO. At a minimum, this individual should have frequent access to the CNO. The balance of four positions are recommended for inclusion in the ranks of the Project Management Organisation.

The logic outlined above is based on several principles borne of lessons learned. The first such principle: staff functional supervisory personnel prior to hiring functional employees. Unattended employees without proper supervisory oversight, support and guidance results in inefficient learning, low productivity, the inception of undesirable behaviours, and poor organisational morale, all at a high cost.

Given our suggested focus on training, building technical training programs and providing quality instruction is critical to success. While the scope of the training program and associated lesson plans are being developed, instructors will struggle initially to support classroom and student contact time. The hiring of mentors is one proven solution. Mentors in each core technical function should be staffed at a ratio of one per each 10 employees. In the near term, these mentors will provide four essential things for their respective employees: 1) supervisory oversight and support, 2) technical instruction augmentation, 3) personal attention often required by young, first-time employees, and 4) a constant means of two-way communication. This approach is based on properly investing in your people. The provision of ample instructional and mentoring personnel for new employees will have a powerful impact on technical learning, professional growth and development, and employee morale and support for program objectives.

As stated previously, the majority of the above in the first five positional priority categories should be nuclear qualified and experienced personnel. Where such staffing is difficult, accommodations should be made. As an example, non-nuclear executives should be supported by the engagement of senior, experienced, nuclear advisors. The need for technical expertise in the ranks of instructors, mentors, and process and program expertise should be obvious. Perhaps not as obvious, is the need to hire nuclear experienced personnel in non-technical functions like HR, procurement, communications, etc. Decision-making in these critical support areas needs to be informed by nuclear principles of operation. Hiring personnel to the wrong standard, engaging substandard consulting support, or communicating without plant operational knowledge can all have long term negative consequences.

What is your hiring priority by process?

Staffing of the organisation should support development and implementation of each of the following processes shown in the chart below:

See Appendix 2 for descriptions for each of the processes above to be evaluated for potential inclusion as part of your operating model.

Plant Licensing — Construction

ECD — FCD — HFT

	Process Area	Priority 1 (YR - 2, YR - 1)	Priority 2 (YR + 1, YR + 2)	Priority 3 (YR + 3, YR + 4)
1	Plant Operation		X	
2	Work Management			X
3	Configuration Management		X	
4	Equipment Reliability			X
5	Loss Prevention			X
6	Materials & Services	X		
7	Nuclear Fuels			X
8	Support – Various	X		
9	Talent Management	X		
10	Performance Improvement		X	
11	Management Oversight			X
12	Independent Oversight			X

Figure D. 11 Process Hiring Priority Chart Source: New Unit Assistance Working Group

What is your hiring priority by program?

Staffing of the organisation should support development and implementation of each of the following programs shown in the chart below:

See Appendix 2 for descriptions for each of the programs to be evaluated for potential inclusion as part of your operating model.

		Plant Licensing		Construction
		ECD	FCD	HFT
		YR - 2 YR - 1	YR + 1 YR + 2	YR + 3 YR + 4
	Program Area	Priority 1	Priority 2	Priority 3
1	Accident Management	X		
2	Ageing Management			X
3	Air Operated Valve			X
4	Benchmarking	X		
5	Boric Acid Corrosion Control			X
6	Chemical Control		X	
7	Chemistry Quality Assurance Program (CYNISP-201)		X	
8	Component Health Program (CHIP)			X
9	Containment Leak Rate Testing			X
10	Control Room Envelope Habitability			X
11	Corrective Action Program (CAP)	X		
12	Cyber Security		X	
13	Emergency Preparedness (EP)		X	
14	Employee Assistance Program (EAP)			X
15	Employee Concerns Program (ECP)			X
16	Environmental Qualification (EQ)		X	
17	Erosion and Corrosion Monitoring			X
18	Export Control	X		
19	Field Observation			X
20	Fire Protection		X	
21	Fitness for Duty (FFD)			X
22	Fuel Integrity			X
23	Health & Safety	X		
24	Human Performance (HU)		X	
25	In Service Inspection (ISI)			X
26	In Service Testing (IST)			X
27	Language Program (e.g. English)	X		
28	Maintenance			X
29	Maintenance Rule			X
30	Motor Operated Valves			X
31	Offsite Dose Calculation		X	
32	Operating Experience (OE)	X		
33	Performance Assessment			X
34	Probabilistic Risk Assessment (PRA)	X		
35	Process Control			X
36	Quality Assurance (QA)	X		
37	Radiation Protection (RP)			X
38	Reactor Vessel Integrity Program		X	
39	Safeguards		X	
40	Steam Generator Management			X
41	System Health Program (SHIP)			X
42	Training & Qualification	X		
43	Margin Management			X
44	Flow Accelerated Corrosion (FAC)			X
45	Plant Lay-up and Preservation		X	
46	Underground Piping and Tank Integrity (NEI 09-14)		X	
47	Welding			X

Figure D.12 Program Hiring Priority Chart

Source: New Unit Assistance Working Group

When should you hire personnel?

Before we begin to answer this question, let us remind you of the first of our four recommended executive performance objectives for success: Staff and prepare for operation early and aggressively.

So far, we have described in general terms a scope of work defined by your operating model, set timing targets for each major project milestones, determined staffing number targets for each function (and in total), and specified hiring priorities. We will now endeavour to provide you a staffing curve.

To create a staffing curve in support of achieving operational readiness, we set rules for our calculations as follows:

1. Start operations staffing at the signing of the EPC contract (i.e. ECD).
2. Use the two-unit generic PWR staffing model as per our assumption.
3. Align to the timings of major project milestones outlined in figure D.2.
4. Pursue hiring in the priority order suggested for each function, position, process and program.
5. Begin functional staffing at the beginning of the designated priority period.
6. Achieve 50% of the functional total staffing target by the end of the designated period.
7. Achieve 90% of the functional total staffing target two years after the designated period.
8. Achieve 100% of the functional total staffing target one year prior to FL.
9. Staff the temporary commissioning function as required to support first and any subsequent unit commissioning. The staffing will go to zero upon the satisfactory completion of commissioning services.

Minor adjustments were made to ensure minimum functional staffing existed where needed to support needed process and program development. The above rules allow time for the processes of employee (or contractor) hiring, onboarding, organisational acclimation, completion of requisite training, and the achievement of a satisfactory level of personal productivity.

When applied, the rules yield the below staffing curve. Greater detail can be found in Appendix 4.

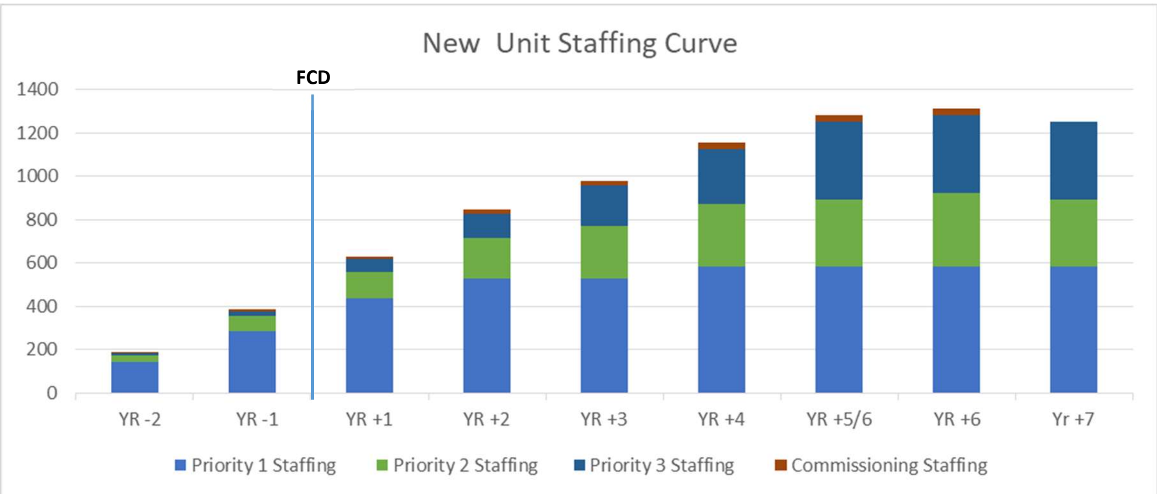


Figure D.13 New Unit Staffing Curve Source: New Unit Assistance Working Group

Starting at ECD, the curve suggests a need to hire at a rate of 214 persons per year for seven years to establish target operations organisation staffing levels. Allowing for an annual attrition of 5%, it is recommended that the initial targeted annual hiring rate be 220 and grow to 270 persons per year in the latter staffing years. (Note: Ideal attrition is considered to be 3% or less; attrition higher than 7% is reason for concern. Annual attrition analysis, insights and subsequent retention actions where appropriate is recommended.)

What are the key enablers for successful staffing?

You must accomplish two things:

1. Create, implement and execute a strong nuclear talent management process.

   See the guidance provided for the Human Resource (HR) function in the functional guidance Section E of this document.

2. Establish and execute a hiring plan in support of your staffing curve.

   Reference the seven staffing questions outlined earlier in the section when developing your hiring plan.

What other staffing concerns should we be aware of when developing our hiring plan?

Consider the following additional points when developing your hiring plans:

- Understand the potential difference between direct hire and contracted employees.

  There are benefits to contracting employees. By way of example, contracted employees can often be staffed and mobilized quickly. As well, performance management is simpler. That said, an investment in long-term employees can create greater certainty for management and greater levels of commitment by employees. During normal operation, such commitment can lead to more careful oversight and scrutiny of plant operation and greater attention to detail when repairing plant components. During abnormal operation, employees often demonstrate the necessary commitment required to meet the highest levels of plant challenge. In the worst of circumstances, industry experience suggests employees are far more willing to step up to protect the public. In recent history, it was the operators at Fukushima that mitigated the consequences of the accident. Contractors left immediately and did not return during the critical stages of the accident. Levels of plant ownership by long-term employees are typically a positive contributor to plant performance.

- Do not overestimate the effectiveness and impact of experienced nuclear personnel.

  Most would assume that experienced nuclear operators with solid personal performance records are highly likely to be immediately effective in helping to staff your organisation and build your operation. Unfortunately, experienced nuclear personnel who have served for long periods of times at plants with reasonable performance often have not developed the requisite skill sets needed to help build, implement and grow your operation. They may understand what the end state needs to look like, but often not how to achieve it. Additionally, because they have not lived the journey, these persons have forgotten the basis, or the “why,” for nuclear standards, programs and processes. Understanding the bases is essential to effectively mentoring new nuclear personnel. The obvious solution is to seek personnel with direct experience building new plant operations or the refurbishment and restart of nuclear units following prolonged shutdowns. Another is seeking personnel with experience in significant change management efforts. Examples may include participation in efforts to achieve significant levels of performance change at a plant (i.e. a significant turnaround); project experience in a major plant change (e.g. the design and implementation of a plant power uprate or a large scale SAP software implementation); or planning, preparation and execution of complex plant outages or large scale, multi-faceted plant modifications. Skills relevant to the planning, development, implementation and execution of major plant improvements or change management initiatives may be directly transferable to your project.

- Appreciate the opportunity, but understand the challenge, of hiring experienced, non-nuclear personnel.

  As necessity dictates, you may need to employ experienced, non-nuclear personnel in key leadership roles. Over the past decades of nuclear operations, the industry has successfully hired significant numbers of experienced personnel, including executives and managers, from non-nuclear, technical fields (e.g. fossil plants, biotechnology lab operations, chemical facilities). When done, it is your responsibility as the hiring organisation to properly prepare these individuals to safely lead a nuclear organisation. The potential success of experienced, non-nuclear personnel is highly dependent on two things: 1) the use of comprehensive plans for personal indoctrination, training and development; and 2) support through effective mentoring. See the discussion in the next section on developing these personnel.

- Understand the opportunity and limitations of seeking new employees at other nuclear facilities.

  A rich potential source of staff hiring is other operating nuclear power plants. Operators from plants with similar technology, maintenance personnel from plants with similar components, and managers from any nuclear plant technology can add quick and immediate benefit to your organisation. That said, you will recall we introduced earlier the notion of the industry being "hostages of each other." One plant's troubles and associated lessons learned should strengthen all plants. The opposite is also true, one plant's benefit should not undermine another plant's success. You will need to be respectful of hiring by your program that potentially undermines another plant's operational safety. WANO will often facilitate feedback from an impacted station in such circumstances.

- Do not overlook the hiring of women for your project.

  Women provide a rich source of technically capable individuals for employment consideration in all potential plant roles. For example, the plant of choice project hired, trained, qualified and staffed a large number of local women in all plant roles – to include the placement of licensed women within the MCR. A number of these women demonstrated impressive leadership skills and earned appointment to key operational leadership roles.

What do you need to consider when attempting to screen and select high quality staff to hire?

The organisation is its people. Who you choose will determine your future. Endeavour to choose carefully and wisely.

Selection boils down to two things: aptitude and attitude. Screen and evaluate for both in your hiring process.

Evaluating aptitude for a young person new to nuclear equates to understanding a person's capacity to learn. It is recommended that a rigorous testing method be used to assess aptitude. Examples of such aptitude testing includes the Plant Operator Selection System (POSS) test for screening potential operations personnel and the Maintenance Selection System (MASS) test for maintenance personnel. These tests and candidate preparation online support are available from the Edison Energy Institute.

For multicultural organisations, language skill testing and evaluation may be required. Interactive face-to-face language testing and evaluation is suggested for non-native language speakers. If you decide to accept certifications, strongly consider only accepting the International English Language Testing System (IELTS) certification. IELTS has the highest degree of examination and certification integrity.

When reflecting on a candidate's attitude, look for school or work history indications of commitment. Examples for new graduates include class attendance or extent of extra-curricular activity. Examples for experienced employees includes the effort and attainment of certifications and advanced degrees. Likewise, involvement in special projects and with organisations like WIN and YGN can be indicative of career interest, enthusiasm and professional dedication.

A career in the operation of nuclear power plants is very challenging. While extremely rewarding, it is technically difficult and often requires long and unusual time commitments. Be honest when characterizing this challenge for new recruits. Doing so allows you to more effectively gauge a recruit's response and enthusiasm for meeting the challenge ahead.

A word of caution: In the event staffing targets are difficult to achieve, there will be pressure to lower the bar on hiring requirements. Do not succumb. Quality versus quantity is always the right answer. As pressure mounts, double your efforts to search for and hire high calibre candidates. Put safeguards in place to ensure standards are met. Should genuine opportunities arise for exceptions, such cases should require formal justification and careful HR management AND functional management review and approval.

Any final concerns?

Managing personnel data and organisational information within your enterprise management system needs to be done accurately and quickly. Underlying management processes, including the approval of organisation chart changes, needs to be executed both effectively and efficiently.

Specifically,

- Define and approve a <u>final</u> organisation chart for the operation early in your program.
- With an eye on the final organisation, define interim organisation charts as your program and project grow toward fuel load and plant operation. Be flexible in the allowances for organisational chart and position changes. Prevent potential employee frustration that can accompany overly restrictive or delayed organisation change rules.
- Ensure the system allows the hiring of replacement personnel prior to the loss of incumbent personnel. Restrictions on such can undermine organisational performance by preventing adequate position turnover.
- Create an organisational category for employees in long term-training for core function positions. This is your training pipeline. Do not confuse the organisation chart by populating these personnel in the plant positions until they have completed their training assignments. A robust training pipeline for operations personnel will need to be maintained for the life of your plant.
- Create a management tool or report that shows organisational staffing against target levels. This tool should provide accurate head count information. It should allow for a plus/minus head count by function to accommodate short-term conditions. Such a tool should enable more effective and efficient personnel management. See the illustration provided in Table D.3 on the following page.

Function	Annual Staffing Target (Year X)	Actual Staffing (Current Date)	Annual Staffing Delta (+ /-)	Final Staffing Target	Final Staffing Target Delta (+ /-)
Operations	140	130	- 10	190	- 60
Radiation Protection	10	12	+ 2	40	- 28
Etcetera …					
Totals	150	142	- 8	230	- 88

Table D.3 Illustration: Staffing Tracker Source: New Unit Assistance Working Group

Building Organisational Capability – Personnel Development

As discussed earlier, you are encouraged to establish a long-term vision of safe and efficient plant operation. Achieving such will be largely dependent on the ability of your organisation to execute the fundamentals of plant operation (i.e. the knowledge, skills and behaviours required to safely and efficiently operate the plant). Mastering the fundamentals is especially important for those persons in the core operating functions. The better your organisation can master the fundamentals, the better your plant's performance will be. Thus, an early area of focus by senior leaders should be the promotion of organisational learning.

What is the role of training in building fundamental capability?

The core of your learning effort will be based on a formal training program led by your training function. Industry requirements will demand this effort be appropriately focused on the core operating functions of Chemistry, Engineering, Maintenance, Operations and Radiological Protection. The training organisation must create and implement a rigorous program for the initial support of personnel qualification. The training organisation must also create and implement a rigorous continuing training program in support of sustaining personnel proficiency. While the training department works to build fundamental knowledge and skills in preparation for personnel for qualifications, it is the line manager's responsibility to challenge, verify and approve that the requisite level of personnel capability has been achieved. Ultimately, line managers are the standard bearers for employee capability and qualification.

A caution: many regulators require, and many utilities employ a systematic approach to training (SAT). The requirements of SAT approach help ensure the creation of a training program that achieves and sustains the required level of learning and capability development by trainees. Consider this only a basic foundation for employee training and achieving satisfactory operational performance. More training and teaching effort will be required to optimize both employee learning and your plant's performance.[15]

Your objective is not to train, but to foster learning by all employees. Organisational leaders at all levels are encouraged to commit themselves to building a learning organisation. A learning organisation can be characterized by the following:

- Active engagement and participation in the training program by all leaders and employees.
- Line manager and mentor engagement with employees in daily on-the-job mentoring, coaching and teaching.
- The use by instructors, line managers and mentors of a challenging set of knowledge and skills testing and verification techniques to include examination, simulator/practical testing, and oral boards to verify employee capability.
- Employee exposure to and engagement in support activities at sister stations.
- Encouragement to explore, understand and take action to employ the historical lessons learned from the nuclear industry.
- Strong leadership commitment to employee growth and development.

[15] Experience in the Use of Systematic Approach to Training (SAT) for Nuclear Power Plant Personnel. IAEA TECDOC No. 1057. English IAEA-TECDOC-1057.

Building a learning organisation will accelerate your efforts toward building a strong foundation for long-term operation and help fuel your later pursuit of performance excellence in all areas of plant operations and nuclear professionalism.

What is the importance of licensed operator training?

The training, qualification and licensure of your plant control room staff as endorsed by your regulator are the most mission critical tasks. No licensed operators mean no plant operation. Furthermore, the capability, capacity and professionalism of your licensed operators will determine the long-term quality and performance of your operation. Your operators are your future.

The licensed operator pipeline is long and difficult. For planning purposes, you should assume that no more than 50% of those personnel entering the program will ultimately achieve license. (Note: future pass rates may improve as your training program and organisational capability to screen, select and prepare candidates improves.)

This training journey and associated timings are depicted as follows:

Figure D.14 Operator License Training Duration Source: New Unit Assistance Working Group

The typical licensed training program is at least 24 months long. The above training program is typically followed by requirements for a six-month, on shift experience at an operating power station. This “hot time” experience will be conducted in the capacity of a trainee. Plant operation will be allowed only under direct supervision of a qualified operator. The operator training component and timeline is the major portion of the critical path timeline, as previously discussed.

How might you build a stronger foundation for future operational excellence?

While the training of licensed operators to support plant operations is mission critical, let us take a moment to suggest taking a bigger step consistent with the philosophy of building a learning organisation. Establish a vision that includes ensuring that <u>every</u> employee understands and appreciates the basics of the plant and its operations. Plan to develop and execute a high-quality program of operational training for all employees to include: nuclear safety principles, key terminology and operating concepts, basic system operation, simulator experience, and plant walk-downs to create plant familiarity. Objectives for such training would include ensuring every employee, at a minimum, can successfully answer the following:

- What makes operating nuclear power plants unique and special?
- What are the main plant components and systems?
- What are the technical principles that support plant component operation?
- How does the plant work?
- What are the bases for plant operation during both normal and emergency operation?
- Why do we do what we do? What is the basis for operational support mechanisms though-out the operating model? How does each tie to the 25 key events that shaped our industry?

- Am I familiar with the plant environ, spaces and equipment? Am I both safe and comfortable (and thus free of anxiety) while in the plant?

An effort to accomplish the above should incorporate a graded approach. First and foremost, the operator license program described previously is the ultimate plant operation training platform. A continuous pipeline of licensed operators should be in constant motion. The objectives of this pipeline should be supplying ample MCR shift personnel to safely and efficiently operate the plant; and allowing for a robust rotation and the promotion of licensed and experienced operations personnel throughout and, as warranted, upward in the organisation.

Second, mid-level managers without current or previous plant operations performance should be required to take a six-month operating license equivalency course. Such courses are well established in the industry. Generic versions of such a course for your specific technology are typically offered by your technology vendor. These courses are both comprehensive in scope and very challenging to the participant. The courses are pass/fail subject to challenging written and simulator examinations. Graduates quickly become more effective supporters of the operations organisation and more helpful and respective of operational decision-making. They also become much more effective participants in such things as ERO membership, CAP screening, system health meetings, operability determinations, etc. Successful completion of this course by mid-level managers should occur within one year of joining the organisation. It should also be a requirement for any key leadership role in, at a minimum, the core operating functions and any operational executive functions.

Third, the balance of all remaining employees should take a robust plant introductory course. Such a course should be two to four weeks long and include simulator and plant time. Employees should take this course within one year of joining the organisation.

What is the key to ensuring effective technical training of all types?

The nuclear industry expects that managers from the line organisation and training work together to monitor and adjust training to best serve the needs of the organisation. The phrase “line manager ownership of training” is the industry term that describes this philosophy of cooperation between the training department and relevant line managers. These line manager customers should be engaged in the process of training development and delivery, to include the following activities:

- Be present for the first day of new training programs.
- Set and reinforce trainee expectations for professional behaviour while in the training environment – do so from the earliest possible opportunity. This should include setting expectations for independent trainee effort during examinations. The consequences for exam integrity violations should be clearly defined.
- Periodically observe training in the classroom, labs and the simulator. Provide formal feedback from the observations to trainees, instructors and training management.
- Regularly assess and evaluate plant performance via plant observation, corrective action process reports, and plant issue/event analysis as a basis for training program input.
- Participate in regular Curriculum Review Committee (CRC) meetings to review plant performance and adjust training to address gaps in employee knowledge and skills.
- Participate in Senior Training Review meetings to review training performance metrics and evaluate overall program health.

Engagement by line managers in the training program sends a strong signal to employees that you are interested in their growth and development. Early engagement is highly beneficial.

What other fundamental skills need to be developed within your organisation?

Efforts to grow and nurture the following four skills will provide significant benefit to your organisation.

1. Event Investigation and Root Cause Analysis: Persons who can be readily mobilized to investigate events, analyse the findings, and accurately conclude the proper corrective actions are key to preventing repeat events as well as improving plant and organisation performance. Varying expertise will be required to address different event types. As an example: the analytical skills required to analyse a plant transient resulting from component failure are significantly different than those skills required to analyse a plant transient resulting from a personnel error. Select personnel with requisite core knowledge and invest in training them in this important fundamental skill. The program foundation for this skill is typically governed by the Nuclear Performance Improvement (NPI) function.

2. Human Error Prevention: Plant performance can be dramatically impacted by events of all types. Reducing personnel errors reduces the potential for plant and organisational events. Providing training and routinely practicing and demonstrating human performance tools are established means to do this. Establish annual training and qualification in this important fundamental skill. The program foundation for this skill is typically governed by the NPI function.

3. Troubleshooting: The physical plant is dynamic. Effectively determining the cause of unusual plant indications, component perturbations, or system abnormalities requires the application of a systematic troubleshooting approach executed by competent and experienced personnel. Troubleshooting such plant occurrences is a higher order skill set. The program foundation for this skill is typically governed by either the engineering or maintenance function or both.

4. Equipment Tagging and Isolation: This plant activity occurs frequently. Equipment tagging and isolation is an important temporary safety barrier intended to preserve plant functionality and protect plant components, the environment, and most importantly, personnel. The consequences of making mistakes in this area can be significant if not catastrophic. Complex tagging schemes can often require a combination of mechanical, electrical, instrumentation and associated drawing reading skills. Furthermore, component tagging and isolation schemes planned and executed in support of plant maintenance outages can be extremely complex. Well planned schemes are required in support of a safe, timely and productive plant outage. The program foundation for this skill is typically governed by the operations function.

How are nuclear professional behaviours established and nurtured within the organisation?

The perception of professionalism by others is largely a function of the behaviours – words and actions – consistently demonstrated by employees that are witnessed by others. The existence of true professionalism is when these same behaviours are consistently demonstrated regardless of the presence of a witness. Becoming a nuclear professional is difficult; the behavioural demands on the employee are significant. The leadership team plays the essential role in behavioural development. Steps to effective fundamental behavioural development include:

- Developing a robust set of accurate, fair and consistent behavioural expectations for all employees of every function. This should be done consistent with industry standards and best practices. Defined behaviours must be specific and observable (See the example of proper nuclear professional behaviours specified for the training classroom below.).

- Communicating expectations clearly both initially and regularly thereafter. This communication should include describing the basis for every expectation.
- The consistent demonstration of these same expectations and standards by leadership team personnel (i.e. modelling desired behaviours).
- Practicing the desired behaviours in dynamic training and exercise scenarios.
- Leadership and mentor observation of employee behaviours in the field.
- The regular assessment of behaviours and feedback to employees.
- A fair and consistent accountability model to include the recognition of proper employee behaviours and a willingness to constructively address and correct improper employee behaviours, up to and including termination for significant and/or repeated failures to conform to desired expectations.

Start the process of building nuclear professionals earlier using these guidelines.

Key Expectations for Nuclear Professionals in the Training Classroom

1. Be on time for class. Return from breaks at the time specified.
2. Stay focused during class and avoid distraction (e.g. turn off phones and non-training electronic devices).
3. Be respectful of the instructor; do not distract others during class.
4. Ask questions. Answer questions when asked.
5. Be respectful of your classmates' questions, answers and opinions.
6. Study after hours to improve personal performance.
7. Help classmates learn before, during and after class where possible and appropriate.
8. Use independent effort during examinations. Do not undermine the development of other personnel by providing inappropriate assistance during examinations.
9. Provide open and constructive feedback on the quality of training when requested.
10. Participate in oral boards and other trainee-related activities outside of the classroom.
11. Avoid absences, including the use of personal leave, during scheduled training.

Figure D.15 Trainee Expectations Source: New Unit Assistance Working Group

What proven techniques exist to aid in the rapid development of the desired level of knowledge, skills and behaviours?

- Dynamic Learning Activities (DLAs): A planned activity on mock plant equipment or simulators designed to allow participants the opportunity to demonstrate the applicable fundamental knowledge, skills and behaviours. These activities are hands on. Effective learning organisations use these liberally to enhance the learning process. Such activities can be performed during specified training hours, during special management interventions, during safety fairs, etc. Small-scale activities can even be used in pre-meeting safety moments. Well planned and orchestrated DLAs have played essential roles in the transition of plant construction behaviours to operating plant behaviours.
- Employee engagement in the field: Many strong nuclear operating organisations have some program and/or expectations for significant leadership presence in the field. One benefit of

such a program is the opportunity for leaders, mentors and operational experts in multiple areas to engage employees in the field. Such field time creates opportunities for employee learning. Question and answer periods while alongside plant equipment and the posing of potential "what-if" scenarios while in the plant create rich employee development opportunities.

- Oral Boards: The training organisation trains; line managers qualify employees. There is no better way for line managers to verify the effectiveness of training and the competency of an individual than to conduct an oral board. A rigorous period of in-depth questioning of an employee can help accurately assess an employee's readiness to go to work. Oral boards can include DLAs and field walks.

Are there any important and proven techniques to help accelerate the development of experienced, non-nuclear personnel?

It is critical to safe and efficient plant operation that a deliberate and systematic approach to personnel development be defined, supported, executed and overseen. This is especially true of non-nuclear executive and managerial level personnel. Development activities for experienced, non-nuclear personnel should include (in preferred order of execution):

1. All executives and senior managers should attend comprehensive nuclear program indoctrination to help quickly gain understanding and respect for the principles of safe nuclear operation. An example of such a program is the multi-week executive education program provided by the Massachusetts Institute of Technology, Department of Nuclear Science and Engineering.

2. All executives and senior managers targeted to serve in core nuclear functions should attend license equivalency training in plant operations. Such programs are months long and include technical fundamentals, system training and simulator experience.

3. All executives and senior managers in the core nuclear functions should attend the multi-week WANO Senior Nuclear Plant Managers (SNPM) course. The course is designed to introduce and reinforce higher order, plant operating principles, and standards for senior plant leadership personnel.

4. Arrange for multi-week job shadowing at a sister nuclear plant during periods of both operation and outage.

5. Engage in a one year or longer secondment to WANO to help gain exposure and deep understanding of industry operating principles and standards. Such secondments typically include multiple plant visits.

6. Participate in a WANO lead peer review or assistance mission.

7. Identify a peer in your new industry from another company or plant. Engage this person routinely. Include discussions on issues, operating experience, and potential corrective actions.

The above developmental activities are extremely helpful for the new nuclear manager. Participation in the above also provides you a credible answer to the question from the regulator or external stakeholders, "So, how are your developing your key non-nuclear leaders?" If your answer looks like quality participation in all of the above, they should be both comforted and pleased.

Scope and Schedule

Your journey is defined by two objectives: 1) create and implement your operating model, and 2) satisfy the criteria for each milestone along the journey. The operating model you have defined, using the guidance in Section C, will define the vast majority of your scope of deliverables. The milestone criteria defined for FCD, the start of HFT, and FL will serve as interim progress markers.

The scope of activities required to achieve operational readiness fall into several categories:

- Staffing – employees and supporting contractors
- Training and qualification
- Policy, process, programs and procedures – document development and implementation
- Support infrastructure – IT infrastructure and software; document and data retention
- Facilities and equipment

There is a priority and logic to developing and implementing your scope of deliverables. Efficiently completing your scope of operational readiness activities is dependent on how you sequence and coordinate each task. All should be captured in your schedule.

An effective nuclear operation executes tasks prescribed by three things: The business plan, the daily schedule, and the corrective action process (CAP). During the march toward operational readiness, the latter two things will be most important.

Your efforts toward operational readiness should be guided by your schedule. Course adjustments and additional actions and tasks will be defined in response to incidents and issues captured in the CAP process. Depending on the level of detail, the total scope of your operational schedule from start (pre-FCD) to finish (FGC) can range from 25,000 to 100,000 line items.

Building a quality schedule is a priority. Doing so requires knowledgeable personnel. An early critical hire is your master scheduler. This person should be a very experienced nuclear professional with ample plant experience and advanced skills with your chosen scheduling tool (e.g. Project View/Primavera). Additionally, this person’s leadership will be required to build a cadre of quality schedulers and to help guide the organisation in schedule development and execution. Accordingly, competencies in the areas of personal interaction, plant technical, and leadership effectiveness will need to be demonstrated.

The body of scheduling and planning personnel are sometimes collectively referred to as a Project Management Office, or PMO. This is a standard project management discipline term. The PMO serves the organisation by doing the following:

- Work with line executives to help define and align the organisation to short and long-term objectives for achieving operational readiness.
- Work with line managers from all functions to help define schedule milestones and associated success criteria.
- Work with line personnel from all functions to facilitate the creation of the <u>scope</u> of operational readiness tasks.

- Work with line personnel from all functions to facilitate the creation of the schedule of operational readiness tasks. These should include both critical path and all other supporting schedule paths.
- Provide the forum for regular daily schedule reporting and review.
- Provide organisational progress reporting on all aspects of schedule performance and progress towards objectives.

A comprehensive and quality schedule is the foundation for the effective and efficient achievement of your objectives. But, day-to-day progress and the ultimate achievement of operational readiness milestones are a function of the organisation's ability to execute the schedule. In addition to having the requisite organisational capacity and capability discussed in the previous sections, you must have the organisational discipline to execute daily tasks in a quality manner.

Organisational discipline is born of three things: leadership effectiveness, personal accountability, and organisational teamwork. Several things must occur to achieve a high level of organisational discipline. First, executives must formally endorse and constantly reinforce the schedule and supporting PMO activities as the organisation's path to success. Second, the leadership team must be aligned to full engagement with the PMO during schedule development, and accountable to and supportive of day-to-day execution of scheduled tasks. Employees and contractors must complete the assigned daily tasks. Finally, the organisation must demonstrate teamwork.

Virtually every schedule activity will have dependencies. The delivery of any one function's small piece of the operating model will require the support of numerous other functions. No organisational function will be successful in isolation.

Of course, you will need to monitor your organisation's effectiveness and your progress to operational readiness. The PMO should provide a multitude of progress measures, to include:

- Resource (scope and manpower) curves
- Scope completion
- Critical path progress
- Work path float* (All work paths)
- Schedule adherence by start (organisation total and by function)
- Schedule adherence by finish (organisation total and by function)

*Float – measure of time by which a given work path either trails (preferable) or exceeds the designated critical path schedule.

The PMO must use the above measures to monitor schedule progress. The PMO should facilitate a regimen of meetings that allow for monitoring of schedule progress. The totality of these meetings should be defined to encompass all levels of the organisation. These meetings should prompt regular course corrections and accountability actions as required to promote enhanced schedule performance. When designed and executed properly, the outcomes of these meetings should be a higher quality schedule, enhanced schedule execution, and, ultimately, improved progress toward operational readiness.

By now, you should have inferred that your schedule will serve not only as your organisation's guide to operational readiness, but do so for the next 100 years of operation. Execution of a quality daily schedule will result in the effective and efficient accomplishment of plant testing and maintenance tasks during online and outage periods. Organisational discipline established in pursuit of operational readiness will have an important, long-lasting impact on plant performance.

What does a strong start toward operational readiness look like?

Industry experience would suggest that the beginning of your efforts to grow and develop an operations organisation, and ultimately to achieve operational readiness, should begin at ECD, typically two years prior to FCD. A start at ECD should allow sufficient time for the staffing and subsequent completion of activities required to attain the interim criteria for FCD outlined in figure D.16 on the following page.

Figure D.16 Operational Readiness Criteria at FCD (T = 0)

The following criteria should be met at FCD to ensure adequate progress toward Operational Readiness.

Plant Licensing:

- Preliminary Safety Analysis Report (PSAR) submitted and accepted
- Construction license received from regulator
- Nuclear Regulation received and understood
- Local non-nuclear regulations understood e.g. environmental & industrial safety
- Compliance with applicable codes and standards understood e.g. IEEE, ASME, ANSI

Plant:

- Site and plant technology selection complete
- Initial operations support infrastructure established
- Environmental parameter monitoring in place

People:

- Approximately 350 to 400 operations people are staffed to include
    - Key leaders for all disciplines (Director level and above)
    - Five key hires defined in Section D.2
    - Process owners for each core process
    - Program owner for each defined program
    - Operations training staff in support of license training
    - Initial class of operations license trainees
- On boarding training and personnel in processing protocols established

Documentation:

- Operating Model Revision 0 written and approved
- Document hierarchy defined and numbering convention established
- Procedure scope (revision 0) defined
- Essentials documents 1 through 5 in Appendix 2 written and approved

Supporting Infrastructure:

- Functional initial operations offices and training accommodations established
- Corporate Enterprise software in place and functional in support of HR, Procurement, IT and Finance functions
- Corrective Action Process (CAP) program in place; Condition reporting functional
- Project Management Office set up; Level 1 schedule established
- Training simulator schedule on track to support planned start of simulator training

Verification of Organisational Performance

- Regular schedule review meeting established; schedule metrics in place and being monitored
- Corrective Action Process (CAP) metrics in place and being monitored
- Staffing curves and targets established; hiring status being monitored
- Commence effort to develop a Nuclear Safety Culture

Source: New Unit Assistance Working Group

Section E: Points of Guidance (by Functional Area)

Guidance based on experience, both successes and lessons learned, are outlined by function. The list of 39 functions referenced here can be found in Appendix 2A. The functions are listed in alphabetical order and not by level of importance. The functions presented are typical of a nuclear plant operating organisation.

For each function presented, guidance is provided in the areas of staffing, applicable policy, processes and programs, procedures, training and qualification, facilities and equipment, and other areas important to the specific functional area.

The 39 functions referenced within this section are:

1. Administration (Administrative Support)
2. Chemistry
3. Commissioning Oversight (Temporary)
4. Communications
5. Decommissioning
6. Document Control & Records Management
7. Emergency Preparedness (EP)
8. Engineering
9. Environmental Management
10. Export Controls
11. Facilities Management / General Services
12. Finance
13. Fire Protection (FP)
14. Fuels
15. Health and Safety (H&S)
16. Human Resources (HR)
17. Information Technology (IT)
18. Integrated Management System
19. Internal Audit (IA)
20. Legal
21. Licensing & Regulatory Affairs
22. Maintenance
23. Management (Senior and Executive level)
24. Nuclear Oversight (NO)
25. Nuclear Performance Improvement (NPI)
26. Nuclear Risk Management
27. Operations
28. Organisational Effectiveness (OR)
29. Plant Projects
30. Procurement & Supply Chain
31. Program Management
32. Quality Assurance (QA)
33. Radioactive Waste Management
34. Radiological Protection (RP)
35. Reactor Engineering (RE)
36. Safeguards
37. Security
38. Training
39. Work Management (WM)

Guidance for the Administrative Function

A competent administrative assistant can significantly improve the effectiveness and efficiency of his or her boss. More importantly, a network of competent, well informed administrative assistants can dramatically improve the effectiveness and efficiency of the entire organisation. This collective impact is particularly important during the rapid growth and change that occurs in a new nuclear organisation. The guidance below is intended to enhance both the impact of each individual administrative assistant and their collective network.

Staffing

- To more readily optimize the productivity of the leadership staff, hire leadership team members and supporting administrative personnel in unison (i.e. minimize the amount of time a senior leader is without administrative support).

Policy, Processes and Programs

- Leverage the administrative staff and their network to enhance change management efforts during the implementation of policies, processes and programs.
- Prioritize the training of administrative personnel in all procedures, especially those procedures tied to organisational logistics, to include: the management of meeting rooms, catering, onboarding and off boarding personnel, IT support, and personnel HR tasks (e.g. time keeping).

Procedures

- Expect administrative personnel to be constantly vigilant of procedure and administrative form changes. Empower administrative personnel to coach employees to adhere to procedural requirements.

Training and Qualification

- Familiarize and align administrative personnel on defined company values. Encourage them to be examples of these values. Welcome them to challenge you, their boss, and others when they may not be living up to defined values and expected behaviours.
- Expect administrative personnel to be conversant in training requirements and record keeping systems. Empower administrative personnel to coach employees to complete all required training requirements on time.
- Train administrative personnel in the CAP system. Empower administrative personnel to encourage employees to write condition reports when warranted.
- Train administrative personnel in the use of the HU tools. Empower administrative personnel to reinforce with employees the use of procedure adherence, verification techniques, three-way communication, and other critical error prevention tools.

Other

- To leverage the network of administrative personnel, establish a formal peer group of administrative personnel. Meet regularly. Establish objectives and plans and execute them with discipline.

- Utilize the network of administrative personnel to enhance two-way communication within the organisation. Encourage them to listen for concerns and rumours. Ask that they suggest opportunities where your communication and interaction with employees might prove helpful.

Guidance for the Chemistry Function

Chemistry is one of six core operating functions. A core operating function distinguishes itself from other functions as follows:

- The function has defined principles and standards of conduct based on industry experience.
- Functional personnel must demonstrate requisite knowledge, skills and behaviours (i.e. fundamentals).
- Functional personnel have the highest level of direct impact on day-to-day operational decision-making and plant manipulation.
- The functions are supported by rigorous initial and continuing training programs. The supporting training programs are based on a formal, systematic approach.
- The functions are the focus of both internal organisational performance oversight and external assessment and evaluation (e.g. WANO).

The six core operating functions are chemistry, engineering (including reactor engineering), maintenance, operations and radiological protection. Subject to effective leadership, strength in plant performance is directly dependent on the capability and capacity of personnel in these six functions.

Staffing

- Define an organisational structure for the chemistry function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Sufficient chemistry organisation capability (approximately 25% of final staffing) must be established early enough to develop and implement the chemistry programs and procedures required in support of the commissioning activities phase. Chemistry staffing scope and timing may also be impacted by the demands of equipment layup and preservation program requirements.
- If the scope of chemistry function responsibilities includes the operation of facilities such as a water plant, chlorination facilities, or waste water processing units, then be sure to plan for the staffing of chemistry personnel with requisite operational skill sets.

Policy, Processes and Programs

- Use EPRI guidance on primary and secondary chemistry sampling requirements for PWR and BWR plants.
- Chemistry programs and processes should be implemented early and phased in to support project needs starting with commissioning activities.

Procedures

- Create a "Conduct of Chemistry" document defining the majority of operations protocols, standards and expectations. Do this referencing with recognized industry bench marks for chemistry excellence identified by WANO. Consider developing a more detailed or specific set of behavioural expectations such as a fundamental expectations document for operations personnel. Regularly discuss the proper application of these principles as the plant progresses from construction through commissioning and on to operation.
- Develop chemistry procedures using a systematic approach. Scope and effort should include:
  - Use of standard procedure formats based on the organisation's procedure writer's guide.
  - Description of the scope of plant systems requiring chemistry interaction to include operation (e.g. water plant) or sampling.
  - Definition of the chemistry requirements (and the basis for each requirement) for each system using industry guidance.
  - Specification of all analytical methods and required instrumentation.
- Procedure development should be phased as needed to support the project. Analysis and operations procedures needed to support commissioning should be developed and scheduled to support targeted activities or milestones.
- Analysis procedure development should coincide with instrument purchase and setup.
- Schedule time for the validation and verification of all chemistry procedures prior to approval for plant use.

Training and Qualification

- Define and reinforce standards of nuclear professionalism right from the start.
- Training and qualification efforts should be phased in as needed to support the project. Classroom training planned too early without the benefit of chemistry equipment, plant (or mock-up) systems, and the opportunity to actually practice or perform each task, will prove ineffective.
- Understand the cultural aspects of the local education system, which may be unique or not aligned with nuclear standards, and plan for any compensatory strategies early.
- Line ownership and engagement in training should begin in the training development phase.
- Recommend that core staff support mentor roles while trainees are assigned to formal training conducted both internally and externally (e.g. vendor training). Mentors should provide technical oversight of the training and supervisory level oversight of trainees.
- Plan and prepare for chemistry personnel involvement in scheduled plant activities. Involvement is important to gain knowledge and proficiency in plant chemistry tasks. Chemistry does not have a simulator, so proficiency is gained by practice.
- Train, prepare for and practice plant chemical spill response.

Facilities and Equipment

- Consider the use of a temporary laboratory facility (e.g. trailer with proper environmental controls) to support construction and commissioning activities. It should be equipped with equipment needed to support these activities. This equipment later can be moved into the appropriate laboratories as they are commissioned meeting environmental and safety standards on a consistent basis.
- Equipment should be specified, purchased, set up and meet operational laboratory QA/QC standards.
- Establish laboratory standards for QA/QC prior to the conduct of laboratory activities in support of commissioning activities.
- If possible, include one operational chemistry expert early in the project during the design review specifically for laboratory facilities, sampling systems, chemical addition systems and chemistry design documents.
- Define and implement standards for chemical use and storage within the lab and throughout the plant in accordance with the Material Safety Data Sheet (MSDS) for required plant chemical liquids.

Other

- Review the schedule carefully. Build chemistry capability (i.e. staffing, training, equipment and program implementation) in phases designed to meet chemistry requirements defined within the schedule for construction, commissioning and operations schedule (e.g. Readiness to support demineralized water production in support of plant flushing requirements). Understand the natural progression of required chemistry support requirements and prepare accordingly.
- For multi-unit facilities, conduct regular chemistry peer meetings to help create and reinforce the use of common governance standards across all operating units. This should include requirements for process and program use, definition of plant operating standards of excellence, and adherence to behavioural expectations, all of which should be captured within the “Conduct of Chemistry.”[16]

[16] WANO GL2001-08 Guidelines for chemistry at nuclear power plants

<u>Guidance for the Commissioning Oversight Function (Temporary Function)</u>

The commissioning oversight function is similar in function to the typical owner construction oversight group. The construction oversight organisation will align itself to construction goals. This cannot be allowed with the commissioning oversight function. These men and women are the operating organisation's first line of defence to ensure the delivery of high-quality plant areas, components and systems that operate to design specifications and operational expectations. This function must report within the operating organisation.

Staffing

- Commissioning staffing is dependent on the contractual model between vendor(s) and owner, and whether there is an existing nuclear program in place in the country.
- For countries without an existing nuclear program, there will be a need to employ expatriates with nuclear experience to supplement local new hires. Local hires should include staff with thermal plant or related industry experience as well as some new graduates. The ratio of experienced vs inexperienced staff should not be less than 1 to 3. Management positions should be filled initially by experienced nuclear staff.
- For existing nuclear countries, experienced staff (about 100 per new unit) should be either hired or transferred from an operating plant after these persons are replaced with an equivalent number of suitably trained, more inexperienced staff.
- Staff selection criteria should include requirements to have proficiency in the language of the vendor documentation (usually English). Recent graduates tend to have better learning skills to meet this requirement but lack the technical/work experience of more senior staff.
- Hire commissioning staff 24 months before the turnover of the first plant system from construction to commissioning. Use this time to support site specific revisions to plant and testing procedures as well as the conduct of other operational readiness activities.
- Ideally, the owner commissions the plant using vendor-supplied testing procedures and supervision by experienced vendor staff. Operating function employees should participate during the three-year period of commissioning activities (i.e. CFT, HFT and PAT). This will accelerate the development of their plant knowledge and skills prior to plant operation. Owner staff in the core operating functions should be employed, fully trained and available to join the commissioning organisation at the start of HFT.
- Upon the start of commissioning activities, to include the turnover of plant systems from construction to commissioning and CFT, organize owner commissioning and operating plant staff as follows: create a commissioning team and an execution team for each of the following five plant system groupings - reactor, turbine/generator, balance of plant, electrical, and digital control systems. The commissioning and execution teams for each system grouping should be tasked to work together and complement each other during the course of system group commissioning activities. These two team types are defined as follows:
    - A technical team would be led by an experienced, technical vendor manager. The technical team would include sufficient numbers of system engineers, each of whom is designated for future system ownership within the assigned system group. These employees will be accountable for the delivery of quality testing program procedures, test result verification, and the capture of test reports and records for both CFT, HFT and PAT activities.

- An execution team would be led by an experienced, operations manager (i.e. licensed experience). The execution teams will include a sufficient complement of field operators and maintenance technicians assigned from their functional work groups. These employees will be responsible for executing planned system turnover inspections, applying system safety tags, and performing commissioning checks for the assigned system group. Prior to HFT, the execution teams would be reassigned as operations shift crews to execute the scope of unit HFT.

- At PAT, some limited numbers of commissioning function personnel will be assigned to support PAT. Remaining commissioning employees should be reassigned to the core operating function organisation to leverage their valuable knowledge and experience with plant equipment and systems.

Policy, Processes and Programs

Procedures

- The delivery of commissioning documentation should be included within the EPC contract. The scope of documentation should include licensing documentation and commissioning administrative and testing procedures. These documents must be developed to meet preapproved writers' guides to ensure consistent quality, level of detail, word choice, units of measure, etc.

- Commissioning administrative procedures should align to the extent practicable to the operations administrative process and program documents to allow for a more efficient transition to operations later in the schedule.

- Commissioning test and operating procedures must have sufficient detail to support the efficient planning of commissioning and assurance activities prior to each commissioning milestone.

- Procedure detail must allow for the specification of the testing logic, duration and resource needs required for each activity. Such detail must allow for the designation of flags indicating which activities must be completed to support each commissioning milestone (e.g. HFT).

- Final detailed commissioning procedures for plant use should be developed at site. These documents – based on the reference plant procedures if possible and available – should incorporate changes to reflect site equipment, local regulatory requirements, and the use of human performance (HU) tools such as independent verification, place keeping, etc.

- System commissioning procedures should be targeted for completion 60 days prior to the turnover of systems from the construction organisation to commissioning. The first procedure executed for each system should include requirements for the field verification of proper installation of systems and components against plant piping and instrumentation drawings (PI&D), and plant component tagging designating the transfer of system and component control to commissioning.

- Detailed repetitive procedures should be well developed for the component tests, as these will be used hundreds of times during the commissioning program.

- A delineation of responsibilities document should be prepared to describe which tests and checks will be completed by construction (before turnover) on a piece of equipment or system, and which tests and checks will be completed by commissioning. This should ensure no gaps or overlap in testing.

- Surveillance and periodic tests should be validated in the field both during and at the end of the commissioning program. Where possible, this testing should replace the need for pre-service testing (PST) to support the in-service test (IST) program.
- System operating procedures should be available one month before system turnover to commissioning and available for commissioning activities/validation.
- A compliance matrix should be developed against licensing requirements (e.g. PSAR/FSAR) to ensure all required testing can be mapped to a specific commissioning test procedure.
- Design changes must be documented and dispositioned for impact/revision of commissioning test procedures as part of the design change process.
- Temporary modifications required in support of commissioning activities should be properly designed, installed and used. Their installation and subsequent removal must be carefully controlled and verified to ensure plant configuration control.

Training and Qualification

- Plant staff should be trained in their respective discipline prior to joining the commissioning team. Commissioning staff may require additional training to the level necessary for their role.
- All staff should complete required HU and industrial safety training (e.g. confined space, working at heights, etc.).
- Man the control room with trained (not necessarily licensed/licensed operators) to support conduct of CFT and HFT. This provides manpower support and tremendous learning for future operators.
- Participation in commissioning activities should be documented by each individual and records maintained to confirm on-the-job participation requirements.

Facilities and Equipment

- Commissioning staff should be co-located with plant staff to the extent possible near the power block.
- Testing equipment should include the standard instruments for electrical, instrumentation and control, and mechanical equipment checks. Specialty equipment should include diagnostic equipment for both motor operated valves (MOV) and air operated valves (AOV), HEPA filters, air balancing equipment/instruments, thermal cameras, relay calibration equipment, and vibration monitoring equipment with software for future plant use. Specialty equipment such as thermal strips for electrical terminations, humidity and temperature monitors, and gas detectors should also be considered.
- Wherever possible, the digital control systems should be installed and commissioned first to allow the historian program to be used to capture equipment operating and performance data, and allow printing of this data for record keeping purposes.
- Relief valve testing apparatus and instrument calibration facilities should be available before commissioning commences.

Simulator

- Simulator use for training of MCR staff on specific PAT should be scheduled well in advance to ensure availability.

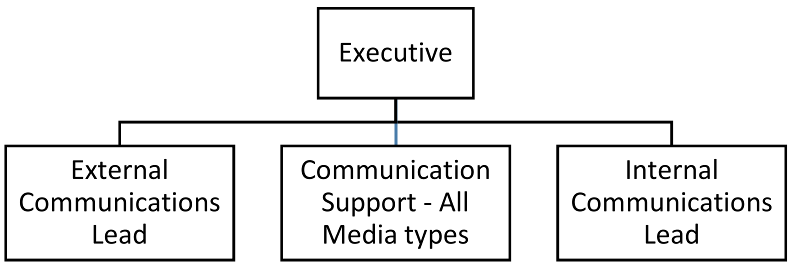
Guidance for the Communications Function

The objective of the communications function is to grow stakeholder awareness and understanding of the nuclear program. In so doing, it functions to sustain and grow project support.

Program stakeholders fall into two broad categories – external and internal. The communications function must develop capability and capacity to satisfy both sets of stakeholders. External stakeholders include the public, IAEA, WANO, government agencies, local politicians, etc. Internal stakeholders includes employees and supporting contractors.

Serving both external and internal stakeholders requires two distinct organisational capacities and capabilities. When communications personnel make efforts to address external stakeholders, they typically do so with full control of all elements of the intended communication: the strategy, the target audience, the delivery medium and the message. Subject to relevant executive approval, it executes its external function largely independent of the operating entity. Internal communications is notably different. When communications personnel make efforts to address internal stakeholders, they do so at the direction of operations line management. They play a support role. When events occur or issues arise, there is a need for timely and accurate employee communication. In such circumstances, line managers will typically define the message and determine the means of communication. Communications personnel must provide rapid support, helpful consulting, and strong facilitation to amplify the communication effort of the line manager. In this way, internal communications helps build and maintain a healthy safety culture.

Whereas external communications is a separate and independent activity; internal communications is a key support service. Early in the project, external communications efforts dominate. As the project evolves and the operating organisation grows, the need for internal communications will also grow. The transition from an external to internal communications focus is difficult. Communications department personnel who love the more proactive, independent and sexy world of external communications may dislike the more reactive, subservient and demanding role of internal communications activity. Thus, building two distinct capabilities, external and internal, becomes a challenge. To do so, the following basic functional outline is recommended:



Source: New Unit Assistance Working Group

Staffing

- For external communications, at a minimum, hire and/or contract nuclear expertise to help write messages and verify technical accuracy.
- For internal communication, hire a nuclear experienced lead.
- Internal communications personnel must partner with line managers and interface regularly with employees and contractors. Hire internal communications personnel with competencies that are complementary of the requirements for effective and timely customer service (e.g. interpersonal skills, responsiveness, response to pressure situations, etc.).

Policy, Processes and Programs

- Establish media capabilities (e.g. video, audio, social media, etc.) that can serve both external and internal communications needs equally.
- The best industry internal communications programs use all forms of interaction techniques, mediums, and social interaction platforms to engage employees and contractors.
- Communications personnel should develop strong ties and meet regularly with personnel from the organisational effectiveness function. Efforts to share insights and work collaboratively can result in enhanced leader and employee effectiveness.
- Internal communications interaction with the NPI function and associated processes and programs can provide communications personnel with program and project insights AND insights from the nuclear industry.
- Communications personnel should play a critical role in the HR process of new employee onboarding. The new employee experience can be dramatically improved by effective and creative communication support. A more positive employee first impression of the organisation can result.

Procedures

Training and Qualification

- Communications personnel will greatly benefit from understanding nuclear operations and familiarity with the plant environment. Plan to include communication function personnel in plant operations training.

Stakeholder Management

- Both external and internal communications personnel will need to develop a strong service model in support of the emergency preparedness (EP) department. EP has a complex set of external stakeholder needs. Examples include routine interactions with external agencies and the need for public communication during the worst of circumstances (i.e. plant events). EP has a complex set of internal stakeholder needs. Examples include the challenge of reaching out to emergency response personnel distributed across all organisational functions and the execution of a cumbersome set of emergency exercises.
- Some functional areas will have significant external stakeholder engagement demands that will NOT require significant communications support (e.g. regulator interface, WANO and IAEA interface). Communications personnel should be ready to support these activities as required but be careful not to interfere with and/or feel obliged to insert themselves into these critical relationships.

Guidance for the Decommissioning Function

Staffing

- Create a team of planners with a mix of nuclear expertise and skills that include decommissioning, radiological waste management, engineering, licensing, strategic planning, cost accounting, and project management.
- Hire experienced staff with decommissioning planning skills to initially establish the function.
- Utilize consultancy services to fill skill set gaps required in the short term while developing services and executing projects.
- Hire junior, developmental staff later to address succession planning and functional continuity.
- Create clear job descriptions for specialist staff positions which reflect the roles required to deliver the business plan.

Policy, Processes and Programs

- Gain familiarity with and deep understanding of decommissioning regulations and regulator expectations before developing supporting policies, processes, programs and procedures. Compliance with regulation is essential.
- Develop and implement a program and plan for the periodic review of the decommissioning plan and associated cost estimates that verifies continued compliance with applicable regulations and accounts for the individual operating and outage history of each nuclear unit.
- Map decommissioning requirements into other functional area processes, programs and procedures. Examples include the engineering design change process, the aging management program, and radiological waste management program.

Procedures

- Recognize that the body of benchmarking material to support the creation of decommissioning operating procedures for new build plants is limited and not readily available.
- Decommissioning planning is dictated by regulation. Create procedures to comply with regulatory requirements.
- Ensure procedures are reviewed often and are aligned with new or changing regulations and national policy.

Training and Qualification

- The body of decommissioning topics is broad. Create a training program that covers only those topical areas required for the role.
- Continuous training and keeping up to date with innovation and industry best practices within the international market is needed in order to maintain a quality decommissioning plan.

Facilities and Equipment

- Specific facilities that create or store radioactive waste need a decommissioning plan and cost estimate that aligns with regulations and the unit/station's decommissioning plan.

Other

- When preparing an initial decommissioning plan as part of the operating license application, determine a parametric decommissioning cost estimate using international standards and bench marks. Adapt this methodology as required to establish a site-specific cost estimate and decommissioning plan.
- Recommend the development of a site-specific decommissioning plan and cost estimate using a decommissioning cost tool and associated database software (e.g. iCAPS).
- Engage critical internal and external stakeholders, including the regulator, during the development of the initial decommissioning plan and cost estimate.
- Explore local options for funding of the decommissioning trust fund.
- Plan for, schedule and conduct an independent peer review of your decommissioning plan and associated cost estimate.

Guidance for the Document Control and Records Management Function

Staffing

- Define the function organisational chart. For each role, define the desired knowledge, skill sets and behaviours needed to optimize process and program development, implementation and execution.
- Begin your staffing effort by hiring highly skilled, experienced and motivated personnel. Leverage these personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Establish the correct work culture. Define expectations and reinforce them constantly. Use metrics and observations to monitor organisational performance.
- Establish functional leadership that motivates personnel to communicate, perform and provide support to the broader organisation.

Policy, Processes and Programs

- Establish a simplified process for procedure changes that uses a graded approach to significance. Categorize procedural issues as minor, intermediate or significant, and have all functional groups agree to these standards to reduce operational burden while preparing for readiness.
- Establish a station procedure review process that allows for the parallel review of procedure changes by multiple functions to improve efficiency and prevent misalignment. This approach should include a clear indication of procedure authorship, review and approval responsibilities. Where applicable, this should identify where approval by multiple functions is required.

Procedures

- Document architecture and content to provide essential infrastructure support for your organisation's operating model. Interface with your organisation's operating model developer, or architect, to align expectations.
- Bench mark the document governance standards of high-performing operating organisations.
- Define the following critical elements of document governance as soon as possible:
    - A procedure and document writer's guide
    - A defined structure and hierarchy for plant procedures and document (i.e. the document architecture).
    - Procedure, document and drawing numbering convention.
- Carefully define the entire list of needed organisational procedures by name. Bench mark to verify completeness. Define functional owners for each procedure, ensuring no duplication of effort.

- Avoid the use of multiple document numbering conventions. Develop a single document numbering structure early. Ideally, align this with the EPC contractor convention if operationally friendly in structure.
- Develop the following critical administrative process procedures:
    - Procedure, document and drawing development, review and approval processes.
    - Procedure, document and drawing records processing.
- Leverage technology to more efficiently process procedures, documents and drawings.
- To reduce and/or eliminate the need for paper record storage, establish a policy for the use of electronic records. Define the standards for retention medium and record format.
- Define performance monitoring metrics and reporting processes early. Review progress status daily, and regularly report out procedure development progress by function to the operations management team.
- If planned, demand the on time (if not early) delivery of plant procedures and documents from the vendor. These procedures will likely require some or all of the following: Renumbering, reformatting, translation, HU tool accommodations, plant walk-down, and more.
- Ensure the bases documents for abnormal operations and emergency procedures are provided by the vendor to support the development of quality operations training materials and lectures.

Training and Qualification

- Define on-the-job qualification requirements for personnel (i.e. required readings, processes and training).
- For each function, schedule the development of high-quality procedures to support training lesson plan development and delivery.
- Enable each function or department to process their own records in a controlled and systematic manner in order to eliminate delays and improve record processing. Train and empower designated record administrators in each functional area to efficiently process records.
- Define the requirements for paper-based versions of computer-based procedures. MCR operations personnel will rely on these in the event of a loss of computers and computer-based procedures.

Facilities and Equipment

- Identify the repository or Electronic Data Management System (EDMS) to be utilized, and have experienced system developers and support team ready to work with the information management team to implement and maintain the system.
- Determine the desired locations of procedure, document and drawing management and record storage facilities. Work with functional managers to determine the need for satellite support locations. Specify the technical and environmental requirements for these facilities and equipment.

Guidance for the Emergency Preparedness (EP) Function

Staffing

- Define an organisational structure for the EP function.
- Begin your staffing effort by hiring highly skilled, experienced and licensed personnel.
- Use experienced personnel to define process and program standards.
- Establish executive alignment around the importance of and desire for the hiring of local, inexperienced personnel as the bases for long-term personnel development and succession planning.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Utilize contract staff to assist during high workload conditions and to provide an independent assessment of EP programs.
- Define the number, size and functional makeup of the planned Emergency Response Organisation (ERO) support organisation.
- Work with HR to establish the expectations and requirements for employees to serve and fulfil ERO roles and obligations. Include these in job descriptions and employment contracts.

Policy, Processes and Programs

Procedures

- Create (based on recognized industry bench marks of excellence) a “Conduct of Emergency Preparedness” document defining the majority of EP protocols and standards. Consider developing a more detailed or specific set of behavioural expectations such as a “fundamental expectations” document for both EP and supporting ERO personnel.
- Carefully validate your program documents and implementing procedures prior to use. Use desktop exercises to scrutinize and refine implementing procedures prior to ERO use. Failure to do so will require significant procedure revisions and demand significant amounts of EP staff time, focus and effort.
- Streamline existing procedures and processes to improve the performance of the ERO and EP staff.
- Include ERO personnel in the review process for EP implementing procedures.

Training and Qualifications

- Develop and implement a process or program designed to sustain high ERO performance in the area of classification, notification and dose assessment.
- Establish the capability to use the training department tracking system to track and record EP training requirements for all employees and contractors with supporting ERO roles.
- Plan to include operations MCR staff early in ERO drills and exercises.

- Continually reinforce high standards of nuclear professionalism during ERO team exercise performance.

Facilities and Equipment

- Confirm adequate access control measures are in place to ensure all emergency response facilities are operational 24/7.
- Develop an agreement between the EP and RP organisations regarding the supply of RP equipment to be provided to the emergency response facilities. Designate responsibility for RP equipment calibration and maintenance.
- Work closely with operations personnel to specify the equipment required to notify ERO personnel when an emergency declaration is made by the MCR shift manager/emergency director. (Note: An emergency director is the lead role responsible for managing the response to an emergency as defined by the EP plan. The MCR shift manager typically fulfils this role until such time the ERO is sufficiently staffed.)

Drills and Exercises

- Define and use a drill and exercise scenario development standard.
- Develop drill and exercise scenarios early enough to allow for independent review of the planned drill scenario and objectives. Make improvements prior to the conduct of planned exercises.
- Ensure that the simulator accurately models all radiation area monitors as well as radiological effluent monitors.
- If an EP simulator is available, develop and maintain a database of online, mini drills to support targeted performance improvement efforts with both on-shift and on-call ERO personnel.
- Enhance information sharing capabilities between on-site and off-site emergency facilities to ensure timely and accurate assessments of emergency conditions.

Program Improvement

- Ensure that all issues of concern (IOCs) raised by the regulator during inspections are related to the EP scope of work. If not, use the CAP system to redirect such concerns to the appropriate functional organisation for resolution.
- Solicit senior leadership support for the EP program. Request and facilitate the constant communication of ERO expectations.
- EP requirements will vary from country to country and regulator to regulator. Challenge the assumptions made by experienced personnel from other countries with different regulators to prevent the development and implementation of low value program elements that may be overly demanding or restrictive. Verify such requirements are required by your local regulator. If not, ensure such requirements add sufficient value to the program prior to use.
- Establish regular and frequent communication with the regulator to confirm alignment, understand expectations, and determine needs.

- Develop guidelines and procedural requirements for maintaining the ERO roster. Define the rules for ERO member participation. Improve efforts to train individuals and develop ERO team proficiency by limiting ERO team member removal or changes.

Off-site Interface

- Work relentlessly to achieve continuous alignment between the on-site and off-site drill, exercise and training program.
- Ensure requirements are in place for sheltering all on-site evacuees. Work with off-site stakeholders to create required processes, plans and procedures
- Define and implement the expectations for coordination between on-site and off-site stakeholders supporting the EP plan. Exercise these expectations regularly. Check and adjust performance as required.
- Engage needed stakeholders in the EP plan and schedule. Request stakeholder participation and engage them in procedure reviews, scheduling of drill and exercises, and the delivery of training.

Guidance for the Engineering Function

Engineering is one of six core operating functions. A core operating function distinguishes itself from other functions as follows:

1. The function has defined principles and standards of conduct based on industry experience.
2. Functional personnel must demonstrate requisite knowledge, skills and behaviours (i.e. fundamentals).
3. Functional personnel have the highest level of direct impact on day-to-day operational decision-making and plant manipulation.
4. The functions are supported by rigorous initial and continuing training programs. The supporting training programs are based on a formal systematic approach.
5. The functions are the focus of both internal organisational performance oversight and external assessment and evaluation (e.g. WANO).

The six core operating functions are chemistry, engineering (including reactor engineering), maintenance, operations and radiological protection. Subject to effective leadership, strength in plant performance is directly dependent on the capability and capacity of personnel in these six functions.

Staffing

- Define an organisational structure for the engineering function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel.
- Leverage experienced personnel to define processes and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Develop and implement mentor role guidance. Provide engineering trainees in the pipeline with supervision, training support and parenting with bench marking of top performers in each engineering area such as system engineering, design engineering, reactor engineering, and programs engineering.
- Be mindful of demographics. Hire mid-career (i.e. 10 to 15 years of experience) individuals to mitigate the gap that can develop when more senior personnel depart after the unit is online.

Policy, Processes and Programs

- Use guidance such as the EPRI Engineering Program Development Guide for Generation 3 and 4 Plants. This guidance provides a systematic approach to the development of 10 important nuclear programs. It provides a process and procedural guidance for the development of programs. This will ensure a common standard and milestone checks for program development and quality. In addition, INPO and EPRI have additional technical standards for specific engineering programs such as motor operated valves, flow accelerated corrosion, air operated valves, etc. that provide many program attributes.
- During engineering program development, develop companion program health reports and notebooks to collect and document information to monitor program requirements. These

health reports and notebooks should be implemented during startup and commissioning to provide an initial program baseline and ensure that the metrics and documentation match the program requirements. It is important that the engineering programs related to equipment performance monitoring and testing detect degradation and allow corrective actions to be implemented before unanticipated failures occur. Engagement in industry user groups, owners' groups and bench marking is important to ensure programs are kept current with industry improvements and operating experience to support safe, reliable equipment operation.

- Develop and implement a configuration control process for the management of temporary plant modifications. Make provisions for the development, review, approval, field implementation, tracking and subsequent removal of all temporary plant modifications.
- Develop and implement a process for the ownership, storage, control, and quality assurance of software. Consider the needs and accommodations for cybersecurity.
- Bench marking and industry reviews of engineering programs are beneficial to remain aligned with industry practices and methods of program implementation.

Procedures

- Create a "Conduct of Engineering" document defining the majority of operations protocols, standards and expectations. Do this referencing recognized industry bench marks for engineering excellence identified by WANO. Consider developing a more detailed or specific set of behavioural expectations such as a "fundamental expectations" document for operations personnel. Regularly discuss the proper application of these principles as the plant progresses from construction through commissioning and on to operation.
- Manage the generation of new processes and procedures. Start from the top and only create new ones if really required. Not doing this can lead to conflicts and confusion when trying to reconcile the various documents.

Training and Qualification

- Develop position qualification guides early. Prioritize the performance of tasks to ensure that the more significant requirements/tasks are executed early. Ensure that qualification requirements are consistent with best industry practices. In addition to generic requirements, provide more specific guidance for positions in safety critical systems (e.g. reactor coolant system engineer, instrument and control engineers, etc.).
- Assign mentors for new personnel and make the mentors responsible to ensure progression at the required rate. Track qualification progress regularly to ensure timely completion.
- Perform observations of mentoring sessions and challenge the quality of mentoring activities. Coaching and reinforcement of behaviours are important.
- Build proficiency requirements into base engineering qualifications so that knowledge of newly developed processes is embedded early.
- Assign engineers to support commissioning activities to gain important system design, installation, and operating information and familiarity.
- Develop an engineering continuing training program.

Design Engineering

- The rules and responsibilities for the transition of plant design authority to the operator must be clearly defined. This transition should begin during system startup testing and be completed as each system is turned over to operations. This transition should be documented.
- A process for system field modifications and changes must be defined. This process must include a detailed review by site design engineers. This review should include a reconciliation of any system changes against the design basis and technical specifications. This effort should be enabled – and not hampered by – full and open access to readily available vendor proprietary information.
- There should be a clear understanding and schedule for the turnover of plant drawings, vendor manuals, design specifications and calculations. If programs are established using preliminary documents, the process of transition upon the issuance of final documents must be clearly defined. Requirements for information traceability, common terminology, and the handling of any unique identifiers should be included.

Systems Engineering

- Hire and start system engineers early enough (latter stage of construction) that they are able to be involved with inspection of internal plant systems. Take pictures and log information on difficult to reach areas. Link this information to three dimensional models where they exist. Ensure they are actively engaged in startup testing and turnover of systems.
- Use the EPRI guidance on plant system turnover to develop guides which detail the specific information requirements for system turnover.
- Engage system engineers in plant systems walk-downs prior to turnover with intent to identify and document component and system deficiencies. These deficiencies should be corrected prior to turnover.
- System engineers need to develop and maintain system notebooks during startup. The primary intent of this effort is to collect and capture baseline system data for later use by the system engineer, and others, as required.
- During this startup period, have the system engineer prepare a system monitoring plan that includes normal operating bands for critical system parameters, data collection frequencies, and alarm or alert limits for identification and notification before the normal band is exceeded. This should clearly identify which points are available for trending in the plant computer system. The startup process will allow the system engineer to observe the key issues and tuning of the systems along with the typical operating characteristics, and give an appreciation and understanding of the system design basis.
- During the process of system turnover, startup and testing, a system health report for each system should be developed. The system health report preparation effort compares system condition and performance against standards of excellence. The system health report, once developed, depicts gaps in system material condition and performance against design and operating performance standards. It provides data as the basis for trending. It highlights and then helps track performance deficiencies, material condition issues, and margin degradation. When system health reports are assessed in the aggregate, important plant insights can be gleaned (e.g. collective impact of deign margin degradation).

System Turnover

- The process of system turnover should include a detailed walk-down of the equipment/system by a joint team of, at a minimum, operations, engineering and maintenance personnel. Other functions when available (e.g. chemistry, environmental, safety, RP, etc.) can also participate and will add value and insight. This process should be guided by a procedure or checklist.

- The process of system turnover should list the scope of system components being turned over, the identification of system boundary points, and the configuration of all components (e.g. open/closed, energized/de-energized). Deficiencies or items yet to be finished should be captured along with issue owner contact information. System turnover, when complete, signals a change in system ownership and control. The responsibility for and the day-to-day rules for system management will change. A complementary communication and coordination protocol should be developed and implemented to promote ownership clarity and efficiency.

- Delays between system turnover and initial testing and/or operation of a system can introduce adverse consequences (e.g. corrosion). Procedures and processes are needed to address system and component protection and preservation during idle periods. Examples of system protection actions include the application of nitrogen blankets, placing system and/or components in dry or wet layup, enveloping cabinets in dust covers, and the installation of protective boundaries to protect equipment from other nearby construction activities. Clearly describe how each functional group is involved with the day-to-day preservation and protection efforts required.

Equipment Reliability

- Develop clear guidance for the development and implementation of the plant initial preventive maintenance (PM) program. Use vendor manual recommendations and industry guidance to determine PM scope and frequency. Develop this program using a cross functional team to include operations, maintenance and engineering. Employ a graded approach when making determinations. Establish and allow the flexible use of grace periods during this period of system turnover PM program implementation. This should help minimize the unnecessary impact of low-value PM deferrals.

- Employ a condition monitoring approach. Systematically gather plant system performance information to determine system use and wear, also known as run time. This information should include component sensor data and performance system monitoring data to include flows, pressures, bearing temperatures, vibrations, etc. Maximize the use of this data to adjust and optimize the schedule for the conduct of PM tasks, thus preventing the unnecessary use of plant maintenance resources. Also, use this information to dictate the need for and timing of predictive maintenance. In lieu of strict time-based requirements, predictive maintenance uses plant information to proactively plan and execute maintenance activities in a timely manner to prevent component failure and system degradation.

- During the initial development of the engineering work scope and schedule for both online and outage periods, carefully determine and assess the need for engineering staff resources and capabilities.

- Inventory plant system components. Generate and electronically store component information in the master equipment list (MEL). Ensure the information is easily retrievable. Complete this activity well ahead of system turnover. The MEL will help determine the count of components of each type across all plant systems.

- Component and equipment failures will occur during commissioning activities. Some components will experience infant mortality (i.e. failure during initial or early use). A program of critical spare parts is needed to minimize the potential schedule impact of such failures. Use industry OE and SME knowledge to predict component failures and associated consequences to help create and optimize an initial list of critical spare parts.

- Work with the procurement and supply department to determine a list of critical spares and the associated level of inventory. Use MEL data, projected component failure rates, and the ready availability of parts supply to establish spare part inventory targets. Use a graded approach to determine the type and target number of spare parts.

- Review of system and component design to identify single-point vulnerabilities (SPVs) must be identified and prioritized during construction to clearly determine and evaluate how SPVs will be eliminated or mitigated.

- Identify the expected life of key components and subcomponents during construction so that it is documented for future generations to help baseline and set up life cycle management programs.

Digital Systems

- Life cycle management for the many digital systems at a new plant needs to consider the product life cycle of some of the digital components since components in these systems may become obsolete between initial procurement and initial operation. When procuring certain digital components (processors, programmable logic controller routers, and so forth), what stage the product is currently in can greatly impact parts availability. Considering how short the relative life cycle is for this type of equipment, because of obsolescence, parts can become unavailable earlier than expected.

Technical Conscience and Critical Thinking

- During all efforts to instil strong engineering fundamentals, introduce and discuss with ALL engineers key concepts like technical conscience, critical thinking and the need for peer reviews. Work to align engineers on the desired approach to appropriately raise and resolve issues associated with their technical responsibilities. Test their knowledge and understanding with the conduct of practical exercises such as:

    - The development of a technical evaluation in support of a technical specification operability determination.

    - The preparation and conduct of a complex troubleshooting process and task.

    - The development of an infrequently performed test or evolution.

- Validate assumptions and strive for practical engineering thinking. Ensure technical theory is effectively translated into the practical with a focus on balancing risks versus costs.

Technical Issue Management

- Identified technical issues should be prioritized according to both risk significance and urgency. For each issue, an owner, resolution milestones, and support requirements should be clearly defined. Track these issues carefully. Conduct management reviews of progress regularly.

- Establish an engineering standard that reinforces the desire for fact-based resolution of technical issues. Sole reliance on engineering technical judgement should be a rare exception, not the rule. During such an occurrence, the basis for judgment should be clearly articulated and documented.

- Develop a process for the identification, documentation, line management review and final disposition of differences in technical opinion between plant personnel.

Other

- For multi-unit facilities, conduct regular engineering peer meetings to help create and reinforce the use of common governance standards across all operating units. This should include requirements for process and program use, definition of plant operating standards of excellence, and adherence to behavioural expectations, all of which should be captured within the "Conduct of Engineering."17

[17] WANO GL2001-05 Guidelines for Conduct of Engineering Support Activities at nuclear Power Plants

Guidance for the Environmental Management Function

Staffing

- Define an organisational structure for the environmental management function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- To retain valuable expertise and plant/project specific knowledge, plan early for a transition of desired staff assigned to the project organisation to the operating organisation.

Policy, Processes and Programs

- Identify all required procedures and the relationship between them through process mapping before starting to develop those procedures.
- Wherever possible, start process and program implementation as early as possible. This will reveal early identification of lessons learned and allow ample time to benefit from them.
- Start the environmental baseline studies as early as possible and allow for scope changes based on initial findings.
- Thermodynamic modelling is essential to site characterization, selection and site/plant layout and design. Invest in collecting required data and developing sophisticated models.
- Make a clear distinction between processes and programs that involve regulatory oversight versus those that do not require regulatory oversight.
- Identify local, national and regulatory requirements.

Procedures

Training and Qualification

- Develop a competency-based training program for the environmental management function.

Site Facilities and Equipment

- Develop a comprehensive site master plan in the early days of the project with emphasis on streamlining logistics. Consider all aspects of urban planning. Example: evaluate site travel logistics between various facilities, especially for large-scale sites with distributed facilities and on-site accommodations. Doing so can significantly reduce time and resource expenditure.
- Incorporate energy and resource efficiency considerations into the design process for project facilities.

The Radiochemistry Laboratory is a critical organisation component of the environmental management function. Building and implementation of a world-class radiochemistry laboratory takes years of effort, needs support and funding from senior management, and requires the dedication and commitment of highly experienced radiochemists.

Staffing

Recruitment is key to the successful operation of a world class radiochemistry laboratory. Your radiochemistry lab will likely require the following types of personnel:

- Senior Technical Personnel – Radiochemistry is not taught at the undergraduate level. Formal education in radiochemistry from an accredited university begins at the Ph.D. level. Such programs graduate five to 10 persons a year. Accordingly, the population of Ph.D. radiochemists is low. These graduates are sought by multiple industries, to include nuclear medicine. The message: Finding and hiring such a person may prove difficult.

- Mid-Level Radiochemistry Personnel – Given the limitation on radiochemistry training at the bachelor's degree level, most personnel that staff radiochemistry laboratories at nuclear power stations have no formal university-level training in radiochemistry. Therefore, when building a radiochemistry laboratory staff, it will be helpful to have a mix of experienced radiochemistry lab personnel (i.e. 5 to 10 years of experience) alongside new recruits to the lab. This mix will allow for the exchange of expertise and on-the-job training (OJT). For a four-unit plant, the lab should have approximately five to six mid-level personnel. These personnel should have a minimum of a bachelor's degree in chemistry.

- Technician Level –These individuals perform most routine operations such as sample collection and routine sample processing. Four a four-unit plant, approximately eight to 10 technicians should be targeted for a fully functioning radiochemistry laboratory. Technicians at a minimum should hold an associate's degree in chemistry.

Policy, Processes and Programs

- Use the following three international regulatory guidance documents to define and build your radiochemistry laboratory capability

  1. ISO/IEC 17025:2005 General Requirements for the Competence of Testing and Calibration Laboratories

     - To define the testing and calibration practices used in your radiochemistry laboratory in support of nuclear plant operation.

     - When determining the competency requirements for laboratory personnel. Competencies should be defined for drawing samples, sample analysis and test equipment calibrations.

     - When specifying the requirements for all laboratory facilities performing tests and/or calibrations in support of your program.

     - Good Laboratory Practices (GLP)

     - Embrace the general philosophy and principles outlined in this guidance.

     - The GLP is a quality system of management controls for research laboratories and organisations to ensure uniformity, consistency, reliability, reproducibility, quality and integrity of data reporting laboratories. GLP guidance was first developed and introduced in New Zealand and Denmark in 1972. This in response to much publicized scandals in the industrial bio-test field. This standard was later adopted and promoted by the Organisation for Economic Co-operation and Development (OECD).

- Although GLP may not be a specific requirement specified by your regulator, the principles and practices are an important ingredient in establishing a well-run radiochemistry laboratory.

2. Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP)

    - This guidance, specific to radiochemistry laboratories, was developed in the U.S and provides guidance for the planning, implementation and assessment phases of projects that require laboratory analysis of radionuclides. MARLAP addresses the need for a consistent approach to producing radio analytical laboratory data that meets a project's or program's requirements. The guidance provided by MARLAP is both scientifically rigorous and flexible enough to be applied to diverse projects and programs. This guidance is intended for project planners, managers and laboratory personnel.

    Note: This guidance will not address the requirements of your nuclear regulator or health and safety authority. Take the effort to review and comply with these requirements and standards separately.

Procedures

- Types of Procedures - There are three main areas of the laboratory sciences: analytical, organic and radiometric. Within this framework exist two procedure types – prescriptive and performance based. Prescriptive procedures are applicable to the analytical and organic chemistry areas. These procedures are followed without exception in the laboratory. Radiometric procedures are performance based. They are laboratory specific due to variations in the local sampling environment (e.g. differences in soil types). Performance-based procedures are verified and validated by each lab using a blind performance evaluation sample submitted to the laboratory. Once the laboratory achieves satisfactory results within the bounds of statistical uncertainty, these procedures are adhered as written allowing for adjustments made during sampling in the early phases of plant operation.
- Standard Methods – There are several sources for radiochemistry lab procedures such as the American Society for Testing and Materials (ASTM), Standard Methods, EPA and U.S. Department of Energy. These organisations offer a wide variety and diversity of laboratory methodologies and offer some latitude in the deviation of methods where performance-based modifications are generally made.

Training and Qualification

- Formal training in radiochemistry only comes from a Ph.D. program in radiochemistry. All other training comes in the form of OJT and short-course training provided by organisations such as the Radiochemistry Society or short courses offered by instrument manufacturers. This limitation on the availability of formal training increases the time employees need to gain technical competence.
- Mentoring - Hire short-term radiochemistry experienced personnel to serve as mentors. Develop and implement mentor role guidance. Provide radiochemistry trainees in the training pipeline with supervision, training support and parenting.

Facilities and Equipment

- Key radiochemistry instrumentation for the laboratory will include:
    - Gamma Spectrometers

- Alpha Spectrometers
- Liquid Scintillation Counters
- Gas-Flow Proportional Counters

Each of these instrument types have their own unique set of challenges and requires a highly trained and dedicated staff to set up, calibrate, operate and provide reliable data for reporting.

- Selection of instrumentation should be thorough and methodical, and requires senior level personnel with decades of experience to identify the most appropriate type. For example, regulators may require that a certain detection limit be achieved. Cheaper instruments may not achieve this, and therefore, great care must be taken in the selection process. Additionally, it is vitally important to establish a long-term positive rapport with the instrument manufacturer to assure successful operations of a laboratory.

Data Analysis and Reporting

- Perhaps the biggest issue faced by radiochemistry laboratories is in the area of data analysis and reporting. Within the field of radiochemistry, too few persons have adequate academic training. This in turn leads to data analysis and reporting issues that can go unnoticed, or worse, reported incorrectly. For example, a technician at a U.S. Department of Energy site reported incorrect data on nuclear waste to be buried over a six month period. An error due to lack of knowledge cost the contractor millions of dollars to dig up, recover and re-sample the buried waste drums.
- Best Practice: Laboratories that produce automated data not touched by human hands provide the most accurate data. Too often laboratory personnel will record data from a computer connected to a measuring instrument and then enter such data by hand into another instrument. Such practices are prone to producing unreliable data.

<u>Guidance for the Export Controls Function</u>

Staffing

- Define an organisational structure for the export control function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.

Policy, Processes and Programs

- Identify a comprehensive list of construction and commissioning activities requiring export control input. Review these against the relevant project milestones and timelines, such as license applications, receipt of export-controlled equipment, and receipt of first nuclear fuel.
- Identify any export control activities requiring interaction with the regulatory authority, the International Atomic Energy Agency (IAEA), or any nuclear cooperation partner (e.g. USA Title 10 of the Code for Federal Regulations).
- Identify national security requirements of people (nationalities) and equipment related to export control.

Procedures

- Produce a framework document that describes the export controls program and the processes and procedures required for implementation.
- Align procedures to national regulatory requirements.
- Encourage governing procedure peer reviews and regulatory reviews and approvals of all procedures.
- Use a company document management system to facilitate regular reviews and updates of all plans and procedures.

Training and Qualification

- Make extensive use of international assistance programs sponsored by the IAEA and WANO.
- Participate in international training courses on export control which are regularly offered by the IAEA.
- Constantly refer staff to IAEA guidelines and standards published in their Service Series.
- Align company job familiarisation guides (JFG) to job descriptions for each post in the organisation chart and monitor staff progress against them.
- Where possible, organise benchmarking visits to export control departments of other operators and suppliers.

Guidance for the Facilities Management / General Services Function

Employee and contractor productivity are key to project cost efficiency and on-time delivery. The strategy, tactics, and day-to-day management of facilities and general support services will have dramatic impact on performance.

Aggressively bench mark projects with similar site and plant configurations as yours. Do this for new nuclear plant projects in various phases of construction, commissioning and operation to capture all relevant lessons learned and best practices deployed throughout the project. Note: The variety of scope and scale of Chinese nuclear power plant projects makes this a strong bench marking candidate.

Staffing

- This is one function where the need for nuclear expertise is limited.
- Define your organisation and staffing strategy based on the size and complexity of your project site.

Facilities and Equipment

- Conduct a study to evaluate the scope of site business and employee needs. Determine what support and service can be provided by the local businesses and/or government services.
- If required for your facility, plan site accommodations based on a wide variety of employee and contractor family configurations: single, married, children. The project is long; be sure to allow for changes in personnel status that will surely occur.
- Where required, allow for separate, quality accommodations for both men and women.
- Understand the site and facility configuration required in support of plant refuel outages and associated contractor support. Build construction accommodations with conversion in mind.
- Create expat villages with accommodations for cultural preference (e.g. catering cuisine, sports, recreation, karaoke, etc.).
- Build a hotel. Use this to house plant staff, contractors and stakeholder visitors as required.

Other

- If a comprehensive and clear vision of operational needs is defined early, you will find that the effort and money expended to build the vast majority of construction and commissioning facilities can be mapped to long-term operational use. They will not be wasted; build accordingly.
- Consider and plan for the eventual sale of site housing to employees. Build accordingly.

Guidance for the Finance Function

Finance, typically a corporate function, is one of *four key enabling support functions that will largely determine the efficiency and effectiveness of the organisation. Any one of these four support functions can help to accelerate or restrain the growth in operations capacity and capability development. Establishing a strong finance function is thus critical to organisational success.

A proper finance function exists to empower line managers to do their job. Policies should be designed to make things happen, not prevent them. Finance personnel should focus on their customers and adopt a mind-set of "how can we get this done?" Respect for policy is required, but finance personnel should not serve as policemen. Finance should tolerate mistakes. When mistakes are made, properly assess, analyse, and take corrective actions to help prevent recurrence. Without a proper level of fault tolerance, organisation progress will be slow and frustrating. It is not hard to figure out that the cost of few mistakes is hugely outweighed by the lost revenue tied to placing the plant in operation. Similarly, respect for budgets is required. Finance personnel should work with managers ahead of time to understand and stay ahead of budget limitations. When circumstances warrant, finance should work with line managers to facilitate the process of proper budget changes and approvals.

*The four key enabling support functions are human resources, procurement, IT and finance. A critical question for each of these functions as they establish their structures, policies and procedures should be, "Are we making it easier for operations to perform their roles safely and efficiently?"

Staffing

- Match finance function staff growth with the growth of the organisation. Don't over staff, but keep one step ahead of the overall organisational growth.
- Building the organisation is an excellent opportunity to develop and train people. Keep a balance between mature, experienced staff and developmental personnel.
- Take time to select the right candidates. A small organisation cannot sustain many hiring mistakes.
- For new entrant companies, hire qualified staff with international nuclear experience. Do not compromise.

Policy, Processes and Programs

- Establish a clearly defined governance model early. Define the financial responsibility, authority and accountability within the operating organisation to empower line managers and avoid confusion.
- Develop procedures early as a priority. Having clear processes and procedures from the start gives the organisation clarity and confidence to execute its work.
- Keep procedures simple and clear. Administration processes should not be complicated.
- Implement an enterprise resource program (ERP) software system early to allow the organisation and system development to grow and evolve together.

Other

- Unlike conventional power plants and other processing facilities which have an operational readiness period of 3-12 months, the operational readiness period of a nuclear power plant is as long as the construction period, which can exceed 10 years. This adds a significant cost to the project that is not fully appreciated when assessing project economics.
- The location of the NPP has a significant impact on the cost of the project. The proximity to an urban area and a nuclear supply chain has a significant impact on cost. Associated costs should be accounted for in the project budget.
- The NPP risk profile makes private funding challenging. Maximize and secure public funds for the project, including significant contingency funds.
- Define the process of budgeting and cost management. Define the roles and responsibilities of line managers in this process. Assign managers the authority to manage their budgets and the responsibility to do so prudently.

Guidance for the Fire Protection (FP) Function

The world of fire protection for nuclear power plants is different. Yes, the protection of the asset and your investment is very important. Accordingly, an effective fire prevention and response capability will be required during all phases of construction, commissioning and operation. But, the threat of fire to nuclear safety during plant operation is unique and significant. The unique threat to nuclear safety posed by fire requires a comprehensive, multi-discipline approach to fire prevention and plant fire response. Additionally, unique demands will be placed on the fire protection function facilities, equipment and response personnel in the event of a nuclear accident.

To eliminate duplicative efforts and reduce project costs, design, develop and implement fire prevention and response staffing, programs, facilities and equipment to be used during plant construction with plant operations in mind.

Staffing

- Define an organisational structure for the fire protection function. Develop this structure with regard for the following capabilities:

  During planned operation, fire response for the plant should include:

  - On shift fire response capability: Immediate response typically supported by on shift personnel from operations, radiation protection or chemistry. These personnel are trained and qualified for fire response and emergency medical techniques.
  - On-site fire response capability, the “fire brigade”: Response within one hour typically provided by on-site 24/7 fire department personnel dispatched with equipment from an on-site fire house
  - Off-site fire response capability: Augmented response within several hours typically mobilized from local firefighting capability

  During all occasions, fire response for all on-site facilities

- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel. Many NPPs hire qualified fire fighters from municipal fire departments.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Hire junior staff from nationally recognized fire schools or programs.
- Policy, Processes and Programs
- Develop a robust management approach for both the planned and unexpected impairment of plant fire prevention system components that are required by plant regulation and technical specifications.
- Develop plant firefighting plans that respect needs for preservation of system separation requirements and the protection of nuclear safety systems.

Procedures

Training and Qualification

- Fire protection personal should have plant operations training. Awareness of plant layout, plant system and component function and priority, fire separation requirements and unique plans for plant fire firefighting all require strong operational knowledge.

- Using the standby, 24/7 firefighting personnel to perform plant surveillance testing and minor maintenance on fire monitoring and response equipment is a standard practice used to improve productivity and minimize site staffing numbers. Define the scope of plant fire prevention and response equipment to be surveyed, tested and maintained by the firefighting personnel. Create training to develop firefighter competencies required to conduct these activities.

- Severe Accident Management Guidelines (SAMG) are used during significant plant nuclear events beyond the plant's design basis. In these events, SAMG guidance directs the use of firefighting equipment to perform nuclear safety actions to help preclude plant fuel damage and radioactive release. Train fire protection personal to use designated firefighting equipment to perform these emergency response tasks. This training should include hands-on practical training in the use of special fire protection equipment required in such events.

- Plan for and support the training of operations, radiation protection and chemistry personnel designated for on-shift fire response. Train and qualify these personnel in fire response and emergency medical (i.e. first aid) techniques.

- Train and qualify operations' department personnel in the plant design requirements for fire prevention and the use of fire response plan procedures.

- Plant fire doors protect plant equipment and personnel in the event of fire. Train all plant employees and contractors in the proper use of plant fire doors. Use practical training to ensure personnel properly close and then verify closed plant fire doors. Reinforce the need to report and document fire door material deficiencies (e.g. broken door latch).

Facilities and Equipment

- Build fire house and firefighting dispatch capability within the fenced in area that surrounds the plant. This area is often referred to as the protected area. This will reduce the time required to respond to plant fires by eliminating delays caused by security gate access.

- Depending on site size, build additional fire house and brigade dispatch capability outside the protected area. Use available local response capability if nearby and readily available.

- For fire trucks and firefighting equipment, define specifications that accommodate the emergency plan and SAMG program requirements.

Other

- Develop monitoring tools to oversee and manage the backlog of plant deficiencies in installed plant fire detection and prevention components and firefighting equipment. Keep the backlog of broken fire equipment low (i.e. less than five) to protect plant fire safety margins.

- Develop monitoring tools to oversee and manage preventive maintenance tasks and planned surveillance tests. Prevent overdue tests and tasks to protect plant fire safety margins.18

[18] WANO Report 2019-06 Deficiencies in Fire Protection

Guidance for the Fuels (Fuel Cycle Management) Function

The fuels function provides essential support to the operating organisation. The extent to which this function is either developed in-house or outsourced is largely dependent on the scope of the owner's nuclear development ambition. New projects often outsource this functional need in its entirety.

The below guidance assumes you have chosen to build a fuels function for long-term support of your operation.

Staffing

- Fuel cycle management is the process of providing reactor fuel that begins with the mining of uranium in the ground and ends with the long-term storage (or reprocessing) of spent fuel. The five capabilities essential to the support of the fuel cycle management are listed below:
    1. Procurement of enriched uranium product (EUP).
    2. Nuclear reload design activity to include design of the nuclear core and the licensing analyses required for all accident and transient analyses.
    3. Selection of fuel assembly fabricator and the supporting quality surveillance of manufacturing processes and activities related to fuel fabrication.
    4. Logistical support for the transportation of fuel assemblies from the fabrication source to the host country plant facility.
    5. Development of strategy and implementing procedures for the short and long-term storage and disposal of high-level radioactive waste, including used nuclear fuel.
- Define an organisational structure for the fuels function. Establish executive alignment around the importance of the pipeline of fuel cycle management engineers and buyers to support the above fuel cycle activities.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Hire personnel with a combination of one of more of the following degrees - nuclear engineering, mechanical engineering, business administration, and geology - to support the management of one or more parts of the fuel cycle.
- Hire high calibre personnel with maturity for the above listed disciplines locally. Nuclear engineers are needed for reload core design and the management of high-level waste.

Policy, Processes and Programs

- Develop a robust quality assurance program needed for the nuclear reload licensing analyses.
- Develop a robust quality surveillance program needed for the surveillance activities related to fuel assembly fabrication activities.

- Establish executive alignment around the importance of developing a national strategy for the management of high-level radioactive waste. It is a very complex and controversial subject that deals with technical, environmental, economic and emotional issues. Early involvement of high-level government and public officials is critical.
- Develop a robust public outreach campaign to educate the public regarding radioactive waste management.

Procedures

Training and Qualification

- Develop a master's degree in nuclear engineering at a local university to provide a long-term, sustainable supply of nuclear engineers.
- Consider the need to train junior nuclear engineers at universities abroad as required.
- Engage the nuclear steam supply system (NSSS) vendor to provide training and qualification support for reactor core reload design engineers. The training should involve intensive classroom training in the basics of analytical methods as well as OJT.
- Plan to use fuel engineers to perform reload design and licensing analyses for the first few plant reloads under the supervision of nuclear plant supplier expertise.
- Ideally, EUP buyers should be trained at EUP supplier offices. EUP buyers should be sent for nuclear fuel buyer training at courses offered by companies such as Ux Consulting or Trade Tech.
- Employees pursuing nuclear engineering degrees should be encouraged to take courses in radioactive waste management.
- Employees responsible for radioactive waste management should be sent to related seminars and conferences arranged by the IAEA. In addition, it is preferable to send these engineers to work with French, Finnish and Swedish organisations who are well advanced in this field.
- Hire experienced procurement managers to manage procurement activities and serve as mentors to junior personnel.
- Encourage fuel cycle management staff participation in related seminars and conferences to keep abreast of new developments and emerging regulatory issues.

Facilities and Equipment

Other

- Procure EUP and fuel assembly fabrication services based on the following major principles:
    - Quality
    - Security of supply
    - Cost
    - Sustainability

- Create commercial flexibility and bargaining power by finding a licensed alternate to your fuel assembly fabrication service provider as soon as possible.
- Establish a contract with the NSSS supplier that:
    - Provides fuel assembly fabrication services for the first three to five fuel cycles, at a minimum.
    - Includes the obligation to train your fuel engineers about reload design analytical methods.
    - Ensures that the incumbent fuel assembly fabricator is obligated to provide data required for the fabrication of compatible fuel assemblies by any new fuel fabricator that you might later find and decide to engage.
    - Allows for the use of the NSSS vendor analytical methods to perform core analysis using an alternate supplier’s fuel assemblies.
- Evaluate the benefits of procuring a supply of EUP yourself and providing it to the fuel fabricator.
- Align fuel cycle management activities to agreements with the IAEA and to other agreements between other governments and your government.

Guidance for the Health and Safety (H&S) Function

This function is responsible for the governance, oversight, support and conduct of some services related to industrial safety. The safety of all personnel is important. Additionally, many external stakeholders will consider your site's industrial safety performance as indicative of your site's nuclear safety performance. This is appropriate (see the discussion of this topic in Section C of the roadmap).

Staffing

- Define an organisational structure for the H&S function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel. Where nuclear experienced staff are unavailable, hire expertise from analogous industries such as conventional power plants, oil and gas, and mining.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Hire expertise in the following areas of concentration: working at heights, confined space, behaviour-based safety, heat stress, hazardous materials, lifting and rigging and electrical safety. No one person can be an expert in all areas, so hiring a team with collective knowledge addressing all areas is important.
- Hire H&S early to stay ahead of rapidly increasing workload and work intensity level.
- Develop guidance for the efforts of mentors to develop junior personnel.

Policy, Processes and Programs

- Implement baseline processes for operational plant use early by leveraging the commissioning team. Their use can help test H&S process and program documents and help accelerate the transition from construction to operation. Ideally, implement these procedures in support of cold and hot functional testing.
- Ensure alignment with leadership and contract partners on the scope and schedule for H&S process and program implementation.
- Establish distribution points within the plant and shops for personal protection equipment (PPE) and other safety equipment. Consider use of PPE vending machines within the plant to control withdrawal and signal restocking needs.
- Identify a procurement coordinator within H&S to facilitate the ordering, obtaining and stocking of in-plant distribution centres for PPE and other safety-related consumables.
- Leverage an observation and coaching program to monitor employee behaviours and identify gaps in H&S rule compliance. Identify areas where reinforcement is required.

Procedures

- Prior to the start of procedure development, determine which safety regulations and standards are applicable. Also determine the targeted level of procedure use (i.e. reference, information or continuous use). Keep procedures simple with clearly defined expectations. Limit expectations to the regulations; making procedural requirements too complex will complicate implementation.

- Develop H&S procedures in parallel with training lesson plan development. Use the final version of an H&S procedure to finalize the associated training needs analysis. Do not wait for final completion of the procedure before starting the training development.
- Produce simple to use, paper-based procedures to back up computer-based procedures.
- Carefully review the scope of organisational procedures to verify that procedures have not been duplicated (e.g. excavation, hazardous materials, color-coding systems, clearance and tagging).
- Ensure that all necessary stakeholders are part of the review process of H&S procedures, and address comments and concerns in a timely manner and prior to approval.
- Use staff compliance with H&S rules as reinforcement of the more general principle of procedure adherence.

Training and Qualification

- Be conservative in your projections for H&S training course participation and class exam pass rates. The pace of personnel sign-up and success will be slower than expected. This is particularly true for contractors and multicultural organisations.
- Designate a member of the H&S team to act as a training coordinator. Work with the training department to analyse, design, develop, implement and evaluate (i.e. the ADDIE process) the H&S training program. Build and maintain a strong relationship with the training department.
- Use a graded approach to the determination of H&S training requirements for the organisation.
- Qualify H&S SMEs as instructors. Use these personnel to help the training department deliver the first run of H&S training and during peak training periods. Assist in the development of full-time training organisation instructors in support of longer-term baseline H&S training needs.
- Train H&S personal in basic plant operations.
- Consider developing a mobile training capability to conduct hands-on, practical training in the work place. As needed, use this to capability to support JIT training.

Occupational Health Process, Program and Procedures Implementation

- Bench mark existing NPPs regarding the scope of specific medical and occupational health services they provide to their employees and contractors. Cross-reference your findings with the requirements of your host country.
- Research and understand the codes and practices of the local medical care community and facilities. Determine the impact on medical case management administration for your facility.
- Define the scope of local safety and medical support services.
- Designate a procurement organisation representative as the primary H&S point of contact to improve the efficiency of procuring essential goods and services.

- Designate an H&S contact to interface with finance and facilitate the timely payment of service providers and product vendors. Train H&S personnel in the navigation of the enterprise software system to help transact vendor payments.

- Identify and implement an electronic medical record software and database system for the management of targeted employee data (e.g. operations-licensed personnel, radiation worker personnel). Use this system to track employee industrial hygiene exposure and manage the scope of needed medical surveillances.

- Ensure that companywide job descriptions are evaluated and amended with the required medical surveillance category. Pre-employment medical records, typically an HR function, should be administered to establish a clear medical baseline for occupational health fitness.

- Conduct training and alignment sessions on the proper use of H&S process and programs with cross-functional stakeholders. Align interdepartmental schedules, reports and communication where interdependencies exists (e.g. case management rehabilitation and return-to-work efforts).

Facilities and Equipment

Other

- Use an integrated scheduling tool (e.g. P6) to schedule and track the development and implementation of H&S processes and programs.

- Review the schedule daily and actively participate in scheduled meetings. Be alert for opportunities to provide H&S oversight, support or JIT training in support of upcoming safety significant activities.

Guidance for the Human Resources (HR) Function

Human Resources (HR), typically a corporate function, is one of *four key enabling support functions that will largely determine the efficiency and effectiveness of the organisation. Any one of these four support functions can work to help to accelerate or retard the growth in operations capacity and capability development. Establishing a strong HR function and process of talent management is thus critical to organisational success.

A proper HR function should empower line managers to do their job. Policies should be designed to make things happen, not prevent them. HR personnel should focus on their customers and adopt a mind-set of “How can we get this done? How can we make line managers’ jobs easier (even if it makes our jobs harder)?” Respect for policy is required, but HR personnel should not serve as policemen. HR should tolerate mistakes. When mistakes are made, properly assess, analyse and take corrective actions to help prevent reoccurrence. Without a proper level of fault tolerance, organisational progress will be slow and frustrating. It is not hard to figure out that the cost of a few mistakes is hugely outweighed by any delay to the project.

*The four key enabling support functions are human resources, procurement, IT and finance. A litmus test question for each of these functions as they establish their structures, policies and procedures should be, “Are we making it easier for operations to perform their roles safely and efficiently?”

Staffing

- Hire nuclear experienced HR professionals to develop a strong HR function capable of properly enabling the new nuclear, operations organisation. Persons with a deep understanding of nuclear standards coupled with mature decision-making will help guide HR and operations program formation.

- Review Section D.2. The strength of the operating organisation for the next 100 years will largely be determined by the quality and quantity of the operator license pipeline. Obtain a license operator training pipeline software program to help determine and manage operator staffing needs. Industry program failure rates can exceed 50%. Build a pipeline with twice or more the targeted number of needed operations personnel.

- Monitor organisation attrition. Conduct a formal assessment and causal analysis annually. Take improvement actions as necessary to optimise attrition within a range of 3 to 7%.

Policy, Processes and Programs

- Competing for high-quality talent will be a never-ending battle. Be creative and cost effective in developing policies that create competitive advantage. Remain aware of what best-in-class employers are doing to distinguish themselves from their competitors. (Note: In many countries, hiring competition for staff with higher order technical competencies coupled with the significant challenges of nuclear plant work, results in a higher level of compensation when compared to other industries.)

- Establish early work rules (e.g. work hours, overtime, work week schedule, leave, etc.) that favour the employer. Doing so will add to the man hours attributable to the project, and help screen out potential employees with suboptimal interest in program success. Remember, it is always far easier to implement future work rule changes that are employee friendly then employer friendly.

- Understand that your employee leave and holiday policy will affect the size of your staff. Your staffing number will be a significant contributor to your operational cost model.
- Develop HR policy that reflect the demands of your site location. Example: Remote sites with on-site accommodations and little to no local infrastructure may influence operational decisions (i.e. 12-hour operator shifts allow greater employee residence and commuting options).
- Where possible, adopt and adapt best practice policies from both the international nuclear industry and from industries within your home country.
- Ensure policy guidance on age does not undermine the need for global nuclear experienced personnel.
- Define a formal means of managing exceptions to HR policy, process and program requirements. Such means should allow for line and HR managers to quickly confer to assess, decide upon, and document program exceptions.

Talent Management Process

A. Talent Acquisition

- Screen for employee aptitude and attitude to include:
  - Test for technical aptitude (e.g. use of the MASS / POSS tests).
  - If applicable, test for operating language competency.
  - Evaluate employee enthusiasm and approach to your project. Ask questions about personal motivation and professional career aspirations. Assess how your project does or does not fit these objectives.
  - Evaluate employee personality fit, especially in multicultural environments. Ask questions about an individual's thoughts and experiences working through ambiguity, dealing with difficult people, mentoring, operating outside a personal comfort zone, and managing through communication challenges.
- Develop a new employee onboarding program that properly prepares, receives, indoctrinates, trains and supports new employees. Complete all onboarding prior to employee turnover to line managers. Onboarding effort should include the following:
  - Pre-arrival information and interface.
  - Company in processing and logistic support to include computer issuance, badges, personnel system input, recruitment/joining expenses, etc.
  - Formal welcome to the organisation.
  - Indoctrination to relevant policies -the do's and don'ts.
  - Completion of targeted annual technical training.
  - Completion of targeted required reading.
  - Logistical support for local accommodations, acclimation into the new environment, and personal support services (e.g. banking).

- Line manager welcome.

  A successful onboarding program should create for the employee a strong positive initial impression of their new organisation. It should also help the employee quickly acclimate to their new work environment and help accelerate their early professional productivity and personal effectiveness. For the line manager, it should create a more ready to work employee. Plan for this process to take at least a week. If done properly, this should dramatically improve the efficiency and effectiveness of all relevant support functions. Establish such means before the onboarding of personnel exceeds 10 new joiners per month.

- Define and implement a formal three to six-month probation program concluding with formal new hire assessment, feedback and continued employment approval, extension or dismissal. Fix hiring mistakes early and easily. Have a defined severance program designed for individuals who are struggling to fit into the organisation.

B. Capacity Building (as required)

- Create capacity development programs using in-country technical institutes. Use these programs to address gaps between the technical competencies available within the local hiring population and targeted staffing needs.

- Engage local high schools and technical vocational institutions to create a pipeline of technicians with special emphasis on field operators and chemistry, radiation protection, and maintenance technicians.

- Engage college-level institutions to create a pipeline of licensed operations personnel and engineers.

- Caution: The number of master’s degree and Ph.D.-level personnel required to establish and run a strong nuclear operation is arguably zero. Applicants with higher level degrees can create expectations for increased pay and positions that are difficult for HR to satisfy. New hires with strong technical skills and practical field experience are highly desirable.

C. Training and Development

- Nuclear technical training is a function critical to achieving satisfactory operational performance. Additionally, the training regimen will need to comply with demanding regulatory requirements and external assessment scrutiny. HR should not be the organisation that designs and delivers core functional technical training for operations, engineering, maintenance, chemistry, and radiation protection. Dependent on the level of nuclear experienced managers within the HR function, it may or may not be equipped to provide the proper level of nuclear grade leadership training.

D. Career Management

- Define core and leadership competencies and incorporate them into personnel assessment mechanisms (see below). These competencies should be aligned with the organisation’s defined core values and the principles of safe nuclear plant operation.

- Implement a formal performance appraisal system. Establish organisational discipline for its use early in the project. A proven way to do this is to make bonus and/or salary reviews contingent upon the timely completion of quality staff performance assessments and the delivery of feedback to employees.

- Complement the performance appraisal system with collective leadership reviews of personnel using supporting tools (e.g. the GE 9 box matrix of employee performance vs. potential). The outcomes of these periodic reviews should provide quality input to your approach to succession planning.
- Establish a philosophy that values operational plant knowledge and experience to include:
  - Persons with operational qualification and competencies are first among equals.
  - Actively promote and encourage young employees to enrol in the operations license training program.
  - Actively promote and encourage (if not require) more senior, experienced, non-nuclear employees to enrol in and pass the operations license equivalency training (i.e. an operator light, six-month training). Require course completion within three years of employment and prior to any plant technical role prior to startup and operation.
  - Actively promote an approach that requires every employee participate in and successfully complete the targeted operational training outlined in Section D. Plan to require this course completion within the first two years of employment.
  - Make operational competency and qualification a critical consideration in succession planning.
  - Create and monitor a colour-coded blueprint of your organisation that highlights where operational levels of competency exist. Endeavour to push every function to higher levels of green.
- HR needs to guide and support line managers in effectively rewarding employees for strong performance and behaviours, and the sanctioning of employees for behaviours counter to a strong nuclear safety culture.
- Create a succession planning program that works to identify multiple quality candidates for each critical technical role and managerial position. Take action to fill gaps where they exist.

Supporting Programs

- HR support is required to enable a strong accountability culture, which, as previously discussed, is critical to creating a healthy safety culture. The approach to and capability for timely, methodical, thoughtful and unbiased incident investigation, assessment and disposition is vital to organisational effectiveness. Timely and fair application of a pragmatic HR policy of accountability will strengthen organisational performance, be well received by employees, and help strengthen the culture. Getting this wrong will undermine individual and organisational performance and the creation of a healthy safety culture.
- Develop an Employee Assistance Program (EAP) to provide employees confidential support for a broad range of personal issues. Employee fitness for duty is critical to safe plant operation and, most likely, a regulatory requirement. Such a program helps promote HR as an organisation with an empathetic and supportive approach.

Procedures

- Procedure adherence is a core nuclear operating principle. This should apply to HR. Your clients will read policies with adherence in mind. Accordingly, write procedures that can be followed step by step and include guidance for managing exceptions to HR policy, process and program requirements.

Training and Qualification

Facilities and Equipment

- Provide a dedicated space for employee onboarding. Equip it for efficient and effective new employee processing.
- Create a dedicated place for career planning. Such a facility should be staffed by a nuclear-knowledgeable career counsellor and equipped with staff employment data and personal performance information. The facility should be secure to prevent unauthorized access to personal information. The facility should provide space for career counsellor and employee interaction.

Nuclear Employee Competencies:

The following core competencies (applicable to all employees regardless of position) and leadership competencies (applicable to all positions supervisor and above) are recommended for consideration and incorporation into HR performance standards and assessment protocols. The competencies are designed to promote a healthy safety culture supportive of safe and efficient, long-term plant operation.

Core Competencies	Leadership Competencies*
Adherence to Safety Requirements	Setting Professional Standards of Excellence
Personal Responsibility	Employee Engagement and Communications Effectiveness
Personal Integrity & Transparency	Cooperation and Teamwork
Error Prevention	Inspirational Leadership; Drive for Sustainable Performance Results in Safety and Reliability
Communication Capability	Pursuit of Continuous Improvement
Interpersonal Skills	Employee Development

Source: New Unit Assistance Working Group

The above is aligned to recommended organisational core values and industry standards of safe nuclear operation. *The leadership competencies cited are aligned with the specific guidance contained within WANO document PL 2019-01 (Rev 0) Nuclear Leadership Effectiveness Attributes

Guidance for the Information Technology (IT) Function

Information Technology (IT), typically a corporate function, is one of *four key enabling support functions that will largely determine the efficiency and effectiveness of the organisation. Any one of these four support functions can work to help to accelerate or restrain the growth in operations capacity and capability development. Establishing a strong IT function and supporting services is thus critical to organisational success.

A proper IT function should help empower all employees and line managers to do their job more effectively and efficiently. IT policies should be designed to make things happen, not prevent them. While policy requirements for cybersecurity, export control, personal privacy and professional confidentiality are required, IT organisational responsiveness when issues arise for employees is important to employee productivity and satisfaction.

*The four key enabling support functions are human resources, procurement, IT and finance. A litmus test question for each of these functions as they establish their structures, policies and procedures should be, “Are we making it easier for operations to perform their roles safely and efficiently?”

Staffing

- Carefully define the IT organisational structure and its interface between the balance of corporate and core operating functions.
- Determine the scope of needed IT services. For each service, define clear responsibilities and service-level expectations.
- Create a flexible staffing plan. Define a long-term, baseline level of project and customer support. Staff this baseline level with long-term employees or contractors. Identify planned periods of high customer need. Create and use a flexible staffing model to support peak periods.
- Create a hiring strategy that identifies and hires employees from a variety of sources. Anticipate large swings in resource needs with varying technical skill sets over periods of time.
- Hire and fill key roles with at least 10% nuclear operations experienced personnel. Use these experienced hires to define governance standards and to coach and develop those persons without nuclear experience.
- Define performance standards and associated behavioural expectations for staff early. Communicate and reinforce these regularly. Reward good performers. Remove bad performers quickly – the pace of service work and change efforts will leave little time for employee performance remediation.
- Work diligently to establish and grow working relationships with stakeholder organisations. Develop and sign partnership agreements with key functions within the organisation. Similarly, form working partnership with key supplier organisations.

Policy, Processes and Programs

- Define a comprehensive governance framework for IT strategy, software and data architecture, support services, and the management of customer demands, project needs, cybersecurity, software/data configuration, and business continuity. Anticipate difficulty integrating software and data.

- Use consultant firms early to help define short and long-term IT strategies, performance objectives and associated indicators, and the scope and schedule for activities required to achieve operational readiness in IT. Review and refresh this effort annually with internal resources. Conduct a major strategy review every three years with external consultants.

- Push the organisation to define core business processes early and prior to scheduled efforts to automate. Anticipate and plan for missing or frequently changing functional SMEs early in the project.

- Identify an SME for the governance of each of the core business processes outlined in Appendix 2.B Engage them individually, and then collectively in business process workshops. Begin the effort to map processes, define and implement automation software, and incorporate data requirements, as follows:

  A. If applicable, study thoroughly the reference plant or operating partner business processes and automation:

     - Decide which processes and practices to incorporate or exclude.

     - Collect as-is process documentation from the reference plant.

  B. Map processes:

     - Define each business process using the functional SME.

     - Integrate processes in a collective SME effort. Use these groups of SMEs to conduct table top validation of processes.

     - Identify functional responsibility for the performance of each process step and integration point.

     - Identify the applicable process performance measures. Assign responsibilities for performance oversight.

     - Document all business processes in procedures. Within these, identify process points of integration.

     - Implement strict and traceable change management requirements for business processes and associated procedures.

     - Strive to minimize changes to business processes and the associated impact on processes, implementation training, software systems, integrations, etc.

  C. Implement supporting software applications:

     - Choose the targeted Enterprise Resource Program (ERP).

     - Define interfacing software for support functions (e.g. scheduling, tagging, NPI processes).

     - Start the process automation project(s) immediately after to-be process definition.

     - Align software to the integrated to-be processes.

     - Build to-be processes in the chosen technology platform(s).

- Use groups of SMEs to conduct software validation exercises.
- Be prepared to operate in multiple project paths at once. Use Agile and ITIL models.
- Stick to the plan. Make changes within rigorous integrated process model governance and only with executive level approval.
- Align to one ERP path even if you start with an ERP and then have a competing conflict across technology, process and people.

D. Manage data needs:

- Define the data scope and its sources
- Define the data architecture.

Procedures

Training and Qualification

- Develop an internal training program for IT staff. Include plant-specific training.
- Work with functional leads and process SMEs for process and software implementation.
    - Use training guidance to conduct a formal training needs analysis using the ADDIE process.
    - Create and use a population of super users to help with implementation training and in field support and coaching.
    - Identify the various end user training populations.
    - Carefully consider the type and timing of training. Be cautious not to waste classroom instruction effort by scheduling too far in advance of practical training.
    - Use practical, hands-on training to the largest extent possible.
- Monitor the need for new employees as the project progresses and the staff grows. Consider adjustments to onboarding training for new hire employees.

Facilities and Equipment

- Hardware – Leverage the best hardware technology available at an affordable cost. Standardize your hardware to the extent possible. Consider disaster recovery methods early. Schedule the acquisition of disaster recovery capabilities early enough to set up prior to key operating milestones.

- Software configuration control - Align processes tightly between the functions of engineering, IT and security that serve both the construction and operating organisations. Audit the implementation and assess the organisation’s use of all software tools. Do this early to identify issues and correct problems as soon as possible. This is important to help effectively manage master data.

- Software security – Understand export control, security and cybersecurity requirements early. Align IT software and supporting processes and data with these requirements. Audit early and often to constantly improve and build software use capability within the organisation. Work with personnel in each function to develop skills and identify and address process and data limitations where they might exist.

Other

- Anticipate that organisational functions may inappropriately rely heavily on software products to serve their needs and solve their problems. Work diligently with functional owners to ensure they fully understand their business processes prior to software automation.

- Form joint innovation teams between IT and business function end users in the pursuit of business process and software changes. Prioritize innovation changes based on business efficiency and effectiveness impacts.

Guidance for the Integrated Management System Function

The integrated management system (IMS) function is responsible for the development, deployment and maintenance of the Operating Model. The Operating Model, as discussed in roadmap Section C, will define the end state of your journey to operational readiness.

Staffing

- Hire a broadly qualified and highly experienced operating model architect. Note: This is an early, important hire for the organisation. The combination of required operational experience, familiarity with the operating model concept and its use, knowledge of industry content, and the ability to explain both content and the basis for such makes finding and hiring this person challenging.
- Steady state, long-term IMS staffing will always be small, and likely just one person. In the early days of your program, during the critical stage of operating model development, expand the staff to include a backup. This action will reduce the risk of program confusion and readiness delays in the event your architect is lost during the early development stage.
- Your architect must have the communication and interpersonal skills to do the following:
  - Interface effectively with all key executives (e.g. CEO and CNO), especially during the early operating model development phase.
  - Develop and leverage relationships with external agencies including IAEA, WANO, EPRI and all local regulatory bodies.
  - Communicate, familiarise, explain, and otherwise teach the organisation the operating model. In doing so, create alignment and support for the model (i.e. gain staff buy in).

Policy, Processes and Programs

- Document a summary description of the operating model within a single document. The model will dictate what your operation will look like and how it will conduct itself. If done properly, operating model terminology, concepts and guidelines will have tentacles that reach into all aspects of your business to include each policy, process, program, procedure, organisational structure, etc.
- Convene the operating model architect with operating executives and functional leaders and SMEs to discuss important topics and make early critical decisions. Examples include: 1) application of the GOSP and associated peer group concept within the organisation, 2) review and approval of policy, process and program documents, and 3) software package selection.
- Define a full document numbering convention and hierarchy of documents.
- Form a collective interface group with the operating model architect and all functional process owners (i.e. SMEs). Their frequent interface and coordination will improve the effectiveness and efficiency of early process and program documentation, enterprise software design, implementation, training and use, and organisational response to relevant assessment results.

Procedures

Training and Qualification

- Hire a broadly qualified and highly experienced operating model architect. The hiring of an inexperienced, backup IMS person is acceptable. This person will have developmental needs.

Guidance for the Internal Audit (IA) Function

The nuclear industry encourages the use of a broad and deep suite of oversight bodies and capabilities. This includes internal capabilities like nuclear oversight and external capabilities like WANO. Assuming your organisation is using a standard industry approaches, internal audit (IA) can and should limit itself to the oversight of the organisation's financial and commercial activities. The use of IA for operational oversight will thus be a duplication of effort. Additionally, IA personnel typically are neither qualified, nor experienced in operational standards. Any efforts toward operational assessment and reporting is often ineffective and confusing to the operations organisation. Finally, external agencies like the IAEA and WANO may struggle to understand or appreciate an operational assessment conducted by a non-traditional IA organisation.

Staffing

- Define an organisational structure for the internal audit function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Develop and implement mentor role guidance. Provide inexperienced internal audit personnel with supervision, training support and developmental guidance.
- Be mindful of demographics. Hire mid-career (i.e. 10 to 15 years of experience) individuals to mitigate the gap that can develop when more senior personnel depart after the unit is online.

Policy, Processes and Programs

- Establish a policy that focuses the efforts of IA to financial and commercial transactions.

Guidance for the Legal Function

Staffing

- Ensure the board of directors includes at least one individual with significant and successful commercial nuclear experience. Ideally, two or more board members have significant and successful commercial nuclear experience with the same or similar technology in order to provide objective and well-informed views for the remaining board members. Establish a board sub-committee with responsibility for nuclear oversight, especially for a company with interests other than commercial nuclear generation.
- Ensure all board members are familiar with -- and have an appreciation for -- the concept that nuclear is different. Have each read and acknowledge that they have reviewed the WANO PL 2012-1 “Principles for Strong Governance and Oversight of Nuclear Power Organisation”.
- Staff your legal organisation with at least one member who has commercial nuclear licensee experience such that the requirements and nuances of nuclear liability within the relevant jurisdiction are known, understood and acknowledged. This is important both before and during contract negotiation and execution with vendors. Liability related to nuclear licensees is not well understood in legal communities external to the worldwide commercial nuclear industry (and is sometimes not well understood even within the community). Nuclear professionals in the legal organisation must be prepared to represent the company, including board members and senior executives in a competent and well-informed manner.
- Staff your compliance organisation with at least one industrial professional who is familiar with the federal and local requirements (non-nuclear requirements) relevant to a large industrial project within that jurisdiction. This includes various permit and non-nuclear license requirements. Overall project safety and success depends on compliance with both nuclear and non-nuclear requirements.
- Place the ECP organisation within a functional department that provides some level of independence from the core operating organisations. The roadmap recommends the legal function.

Policy, Processes and Programs

- Create a program governance document that incorporates the elements of WANO PL 2012-1 “Principles for Strong Governance and Oversight of Nuclear Power Organisation”
- Define clear roles and responsibilities for each of the owner organisation, the EPC contractor, the architect-engineer, the operator, the asset owner (if different than owner or operator), and the grid interconnection entities. Do so for each of the following phases:
    - Commercial contracting
    - Site evaluation
    - Site preparation
    - Construction
    - Commissioning … to include cold functional testing (CFT) and hot functional testing (HFT)
    - Plant startup and initial criticality

- Low-power physics testing
- Power ascension testing (PAT)
- Commercial operation (COD)

Capture these roles and responsibilities for each phase in a formal document and matrix.

Consider the use of the terms care, custody and control of the plant systems, structures and components. If the Engineering Procurement & Construction (EPC) contract is not yet finalized, incorporate the concept and terminology care, custody and control into that contract. The basic definition of these three terms:

- Care – the decision-making and associated actions tied to plant component and system maintenance and preservation efforts.
- Custody – the ownership of the asset.
- Control – the decision-making, authorization and action tied to plant component manipulation and system operation.

Caution: A standard non-nuclear EPC contract will not work for a commercial nuclear plant intended for licensure by a regulator. Ensure that at least one member of the EPC contract negotiation and drafting team has significant nuclear plant commercial and regulatory/licensing experience.

- Define an approach that indemnifies contractor and consultants from the nuclear liabilities tied to third country impacts of nuclear events. After plant startup, no credible contractor will support your operation without this critical safeguard to financial risk.

Procedures

Training and Qualification

- Train the senior leadership team on the company's formation document(s) and other governance documents. This should include those activities requiring board or shareholder approval and any delegation of authority from the board to the chief executive and operating executives.
- Ensure corporate board and senior executive training includes familiarization with the facility and operator licensure requirements of the nuclear regulator. The board, the executives, and the senior leadership team must understand the roles, responsibilities, and the authorities of the control room crews and the licensed or licensed operations staff.
- As soon as practical, send board members and executives without commercial nuclear experience to the WANO (or INPO) recommended training sessions.
- Train ECP personnel in proper issue and event investigation techniques.
- Train ECP personnel in the basics of nuclear plant operation.

Employee Concerns Program (ECP) - A program supporting a healthy nuclear safety culture by providing employees and contractor workers with an alternative and independent process to seek intervention, consultation or independent resolution of nuclear safety concerns in cases where individuals feel they are uncomfortable or unable to raise issues to management.

ECP Staffing

- Define what the ECP is and what it is not. Train the organisation on the proper use of the ECP program to prevent inappropriate use. Eliminate employee frustration by describing how this program integrates with the CAP program and other employee reporting and feedback mechanisms.
- Ensure the overall project has at least one ECP person and office available to employees and contractors on-site and at other project support offices.
- Coordinate with contractor companies to ensure that roles and responsibilities for ECP-related activities across the project teams are well understood. Communicate the results of those discussions and agreements with all project personnel. Depending on the jurisdiction, the licensee or construction permit holder may have a regulatory obligation to remain cognizant of all ECP activity affecting license or permit activities. All project employees and contractors should know preferred options for seeking ECP assistance, either within their own company or as part of the larger project.
- Select at least one ECP professional with nuclear experience. All ECP persons should have the key personality traits of personal integrity and maturity and professional judgement, and discretion.
- Have ECP resources join industry peer groups (e.g. NAECP) or perform bench marking with well-respected ECP industry colleagues to observe what good looks like.
- If a large fraction of the organisation contains a certain nationality or regional/cultural background, ensure at least one member of the ECP staff is selected to be approachable and available for intake from each of these large fractional groupings. This member (or members) will be able to provide valuable insights during interviews of individuals from that cultural grouping.
- Consider addressing ECP expectations in standard purchase order terms and contract terms with vendors.
- Create an ECP document or series of ECP documents that covers:
    - A description of the program, including how it relates to other employee issue reporting options.
    - A series of expected activities for an individual wanting to raise an ECP concern.
    - A series of expected activities for ECP professionals from concern or issue origination to the provision of feedback to the concerned individual.
    - Investigator guidelines
    - A clear distinction between what ECP has the jurisdiction to do (e.g. investigate and substantiate (or not substantiate) each issue raised) and what it does not have the jurisdiction to do (e.g. determining and assigning personnel discipline and or other corrective actions. Such actions are for the management team to determine and execute based on the conclusions of an investigation.).

- Ensure program documents clearly state the difference between confidential intake information and anonymous intake information, including how the activities or steps in the overall ECP process may differ for each.

Employee On boarding and Supervisory Training

- Train each incoming employee and contractor on the available and appropriate options for raising concerns. These should include CAP and ECP.
- Train and qualify ECP investigators. Maintain a list of qualified investigators. Note: some of these persons may reside in other functions.
- Include the concept of a Safety Conscious Work Environment (SCWE) and the governing principles of a robust ECP program as part of basic supervisory development training.
- Train supervisors and management regarding the two distinct phases of any investigation: the investigation to prove or disprove the allegation (done by ECP or another investigatory resource) and the resulting disciplinary or other action taken as a result of the investigation findings. Ensure they know that they, as supervisors and managers, are responsible for this latter phase (not the ECP staff).19

[19] WANO PL 2012-1 Principles for Strong Governance and Oversight of Nuclear Power Organisation

Guidance for the Licensing & Regulatory Affairs Function

Where a new nuclear project is initiated in a country with an existing nuclear regulatory framework, the expectations and the basis for interface and relationship management should already be reasonably clear. For a new project in a new nuclear country, you and your regulator will grow and develop together. In such a circumstance, the effort to build and evolve the licensing program and critical regulator relationships will be significant. The advantage though is the opportunity to influence and shape regulatory policy, framework and requirements to the needs of your plant and program, and to do so optimally.

Staffing

- Define an organisational structure for the licensing function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel with varied nuclear backgrounds. Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Establish and maintain a core group of licensing project personnel throughout the project. Use this group for the construction and subsequent operating license submission efforts. This will allow for knowledge transfer, consistency of approach and administration, and the development and maintenance of an effective regulatory interface and relationship.

Policy, Processes and Programs

- If the language of the contractor is different from the language to be used in the licensing process, require the contractor to use technical translators on all licensing documentation to ensure that the documentation is accurate. Likewise, the utility should hire appropriate translators so that difficulties in verbal and written communication are avoided.
- Engage the regulator and other stakeholders in the country that will have a direct impact on the ability to license the plant (e.g., emergency response, security, police, military, etc.). Work with them to understand and support their role in the licensing process. There may be a need to create new agencies or support organisations, especially in new nuclear countries.
- For major license applications (i.e., construction or operating), establish a lead in the licensing organisation for each topical area of the application and a corresponding lead in the regulator to facilitate resolution of issues that arise in the regulatory review and of the application. This should be done for the first license application and maintained until the plant obtains the operating license.
- Establish licensing procedures related to regulator communication and commitment management very early in the project. Use these processes to record and track the outcome of regulator interface activities.

Procedures

Training and Qualification

- Provide the licensing organisation staff training on plant technology and operation, the operating model, familiarity with critical organisation processes, programs and procedures, and all regulatory processes and protocols.

- Plan for and conduct training for the operations staff regarding the regulatory structure, the authority and responsibility of the regulator and the operator, and the protocols for regulator interface and interaction.
- Conduct joint training sessions with your operating staff and the regulator’s management and technical staff as soon as the project contract is signed. Grow an understanding and appreciation of the chosen plant design together.

Facilities and Equipment

- Locate the licensing organisation close to the regulator’s offices (in same city and easy access) so face-to-face meetings are easily accommodated.
- Establish a secure cyber link (i.e. shared, secure website) with the regulator to allow for the rapid transfer of information and communications record keeping.

Regulator Interface

- Build a good working relationship with the regulator from the start by having frequent meetings to discuss topics of interest such as needed regulations, regulatory processes, standards for interface, etc.
- Identify all regulatory bodies that will have authority over the project early and initiate discussions with all to ensure that there are no duplications or conflicting requirements. Try to keep all nuclear related regulatory requirements under a single regulatory authority.
- Involve the regulator in the contracting phase of the project so information provided to the bidders regarding the regulatory requirements are consistent with the regulator’s approach.
- Once the contract is signed, provide pertinent plant technology information to the regulator as soon as possible to begin the process of regulatory familiarity.
- Conduct frequent meetings between regulator management and operations management to share information and to gain a common understanding of issues during the licensing process.

Legal and Regulatory Development

- Establish a process with the regulator that allows for the early review and comment on draft regulations by you, the operator. Do this to help ensure a common understanding of pending regulations or regulation changes and to ensure proposed regulations can be implemented.
- Adapt regulatory standards that are existing and proven in other countries wherever possible to avoid a first-of-a-kind standard in the world.
- Strongly consider adopting the regulatory requirements and processes of the country of origin of the contractor if possible. This will allow for efficiencies in both developing license applications and regulatory review.
- Consider inviting the regulator (and other supporting stakeholders) to participate in targeted benchmarking activities (e.g. conduct emergency plan benchmarking trips to other operating nuclear power plants with established emergency plans to tour facilities, discuss processes, and observe emergency exercises.). Learning together can help the process of both establishing and satisfying regulatory requirements.

License Applications

- Establish a licensing strategy and obtain regulator concurrence as early as possible so applications are made and licenses approved when needed to support the construction, commissioning and FL schedule.

- As part of the licensing strategy, consult with the contractor to identify opportunities for application and receipt of limited construction licenses that could be obtained early to enhance the project schedule. Example: A licence allowance for preparatory work (e.g. basemat preparation, rebar installation, etc.) in support of FCD so that concrete installation can begin as soon as possible after the receipt of an approved construction license.

- Structure license applications to include as much scope as possible to avoid unnecessary or duplicative license applications. For example, if a manufacturing license is needed for long lead items (e.g. reactor vessel, steam generator, etc.) obtain a single license for all units in a multi-plant site at the same time.

- Use a reference plant concept if possible where an identical plant is already licensed and operating. The license application will identify and justify the differences from the reference plant. This will allow the regulator to leverage the reference plant regulator's review and focus on the differences. This can aid and accelerate the regulator's review and approval.

Guidance for the Maintenance Function

Maintenance is one of six core operating functions. A core operating function distinguishes itself from other functions as follows:

1. The function has defined principles and standards of conduct based on industry experience
2. Functional personnel must demonstrate requisite knowledge, skills and behaviours (i.e. fundamentals).
3. Functional personnel have the highest level of direct impact on day-to-day operational decision-making and plant manipulation.
4. The functions are supported by rigorous initial and continuing training programs. The supporting training programs are based on a formal systematic approach.
5. The functions are the focus of both internal organisational performance oversight and external assessment and evaluation (e.g. WANO).

The six core operating functions are chemistry, engineering (including reactor engineering), maintenance, operations and radiological protection. Subject to effective leadership, strength in plant performance is directly dependent on the capability and capacity of personnel in these six functions.

Staffing

- Organisational Structure:
  - Define an organisational structure for the maintenance function.
  - Clearly define maintenance roles and responsibilities. Work with other key functions to define interface roles and responsibilities (e.g. engineering and operations).
  - Create a maintenance organisation structure that supports both efficient online and outage execution. Make allowances for easy work hand offs between mechanical, instrumentation and electrical disciplines in line with industry standards.
  - Build a maintenance team comprised 40% with personnel that have deep subject matter expertise (SME). This will aid in effective knowledge transfer, a robust system turnover process, and the creation of maintenance standards in compliance with regulatory requirements and in line with industry (i.e. WANO) expectations.
  - Define your approach to both corrective and preventive maintenance. Determine an approach to address scheduled and emergent maintenance activities. Consider the application of an industry best practice referred to as the Fix It Now (FIN) team concept to efficiently and effectively manage emergent work activities.
- Personnel Selection:
  - Establish clear guidelines in line with WANO fundamentals for the selection and development of maintenance leadership positions.
  - Begin your staffing effort by selecting and hiring highly skilled and nuclear experienced personnel.

  - Leverage experienced personnel to define process and program standards. Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
  - Evaluate and select candidates that are uncompromising to maintenance and safety standards and have a bias to resolving plant issues correctly the first time.
  - Hire competent individuals with a willingness to learn who are open to change.
  - Hire personnel with proficiency in defined plant operating language.
- Development & Alignment
  - Limit the turnover rate of senior staff and/or pair new to industry individuals with suitable SMEs to allow for smooth transitions and sustainability of processes and functions.
  - Conduct and record regular meetings between the maintenance department leadership and contractor leadership teams and workers to maintain alignment and identify and address important issues.

Policy, Processes and Programs

- Evaluate site location, plant features, and the availability and quality of local industrial support services prior to developing maintenance strategies and determining the need for contracted versus in-house maintenance staff.
- Create maintenance programs that are in line with industry best standards and operating experience.
- Early in the project construction phase, develop a maintenance PM program to support the planning and execution of preventive maintenance tasks and the collection of relevant data for plant components and systems turned over to operations.
- Identify the scope of PM program tasks. Develop supporting task plans and maintenance procedures. Doing so will aid in plant component and system preservation and the identification of component spare parts, and help meet regulatory requirements and WANO expectations.
- Competent and adequate resources to develop maintenance programs and processes should be made available to allow for continuous review with high volume output.
- Reach agreement with the contractor to align their procedures to the plant’s maintenance procedures once it is established. Agree on transition strategies early in the process to allow for effective implementation of the maintenance programs.

Procedures

- Create a “Conduct of Maintenance” document defining the majority of operations protocols, standards and expectations. Do this referencing recognized industry bench marks for maintenance excellence identified by WANO. Consider developing a more detailed or specific set of behavioural expectations such as a “fundamental expectations” document for operations personnel. Regularly discuss the proper application of these principles as the plant progresses from construction through commissioning and on to operation.

- Create maintenance surveillance and safety-related procedures to ensure that the maintenance checks for the FL safety requirements are rigorously tested prior to implementation.
- Develop maintenance work procedures in phases based on execution periodicity: 1) activities < 18 months, 2) activities < 3 years, and 3) activities > 3 years.
- Partner early with licensing when engaging the regulator to explain the maintenance procedure process and how it will satisfy regulatory requirements.
- Establish interim processes and procedures as well as transition procedures to guide the maintenance program to full implementation.
- Verify and validate maintenance procedures and establish a clear timeline for cross-functional reviews.
- Define HU tools' applicability for all maintenance procedures (e.g. place keeping, verifications, etc.). As required, make HU accommodations for computer-based procedures.
- Verify that the vendor manuals are transferred with every system turnover or component turnover. Verify that all settings and design specifications are effectively incorporated in a searchable computerized system to allow for easy retrieval of information during procedure development.

Training and Qualification

Training:

- Build or purchase maintenance simulators for each discipline to allow for an effective initial maintenance training program. The same simulators can be used for contract worker assessments and continuing or JIT training on infrequently performed tasks.
- Line managers should have clear ownership of the training and allow SMEs to participate or develop additional training material to enhance the training lessons.
- Incorporate expectations for the demonstration of maintenance fundamental and HU tool use in all maintenance training activities, especially practical training. Use demonstration as a standard for successful course completion.
- Establish a competency index for each discipline that provides an indication of operational readiness and competency to perform maintenance tasks.
- Simulators for I&C-related training should be purchased early in the project to allow for testing of the maintenance safety and surveillance procedures, training on system integration, especially advanced levels of fault finding.
- All technical courses should have a practical portion that allows for demonstration of competence and allows for independent review of an individual's understanding.
- Define and reinforce training standards for maintenance personnel. Include standards for exam integrity and communication proficiency in the chosen operating language.

Qualification:

- Ensure the maintenance qualification process is clearly defined for both permanent and contractor personnel, especially where it concerns equivalencies. Paper-based equivalencies should be an exception rather than the norm.
- Success in training should require a student to prove theoretical competence by some form of examination. Line management should verify competence with infield demonstration and/or oral review panels prior to granting qualification. A demonstration of competence should include demonstration of both technical and administrative compliance to standards and practices.
- The training record system should be easy, simple to navigate, and available to line managers to verify worker qualification prior to the assignment of plant maintenance activities.

Facilities and Equipment

- Conduct SME walk-down inspections and acceptance reviews of all maintenance facilities prior to turnover. Verify adequate functionality and compliance with industrial and safety requirements.
- Establish centralized maintenance workshops to reduce the time required for multi-disciplinary (i.e. mechanical, electrical, instrumentation) activities.
- Determine the scope of supporting maintenance facilities required and build them. Consider the need for separate maintenance shops that can support equipment calibration, rigging, welding shop, breaker repair, lubrication, painting, mechanical work, electrical work and instrumentation repairs.
- Develop a complete maintenance equipment/tool inventory list, and procure three years prior to FL. Do this to allow adequate time for procurement, calibration and procedure development, as well as training on these tools and equipment.
- Identify the scope of specialized equipment and tools required for predictive maintenance tasks to include thermography, vibration analysis, relay calibration, and other diagnostic tools required for motor operated valves (MOVs), air operated valves (AOVs), and snubber testing. Identify the procedure and training needs for use of this equipment.
- As applicable, agree on the turnover strategy of maintenance and testing equipment (M&TE) from the contractor. Define equipment acceptance standards and the process to address equipment that is found out of tolerance.
- Assign single point accountability for each workshop and establish clear guidelines and standards in advance. Do not accept substandard safety standards or practices.
- Verify that adequate maintenance repair facilities exist for the future scope of “clean” (i.e. non-contaminated) and contaminated maintenance work activities. (Note: the scope of contaminated maintenance work will expand rapidly after the commencement of plant operation.).

Other

- For multi-unit facilities, conduct regular maintenance peer meetings to help create and reinforce the use of common governance standards across all operating units. This should include requirements for process and program use, definition of plant operating standards of excellence, and adherence to behavioural expectations, all of which should be captured within the “Conduct of Maintenance.”20

[20] WANO GL 2016-03 Maintenance Fundamentals at Nuclear Power Plants

Guidance for the Management (Executive and Senior Plant Level) Function

As discussed earlier, your operational objective is to build a solid foundation in preparation to operate your plant(s) safely and efficiently for the next 100 years. The management team should embrace and focus on the following four performance objectives in pursuit of operational readiness:

1. Prioritise safety at all times.
2. Staff the operating organisation early.
3. Promote organisational learning.
4. Communicate constantly.

A leadership team focused on the above will accelerate organisations efforts toward high quality and timely operational readiness.

Leadership team alignment is critical. The organisation must see and hear the message from its leader. To create alignment, a common vision of the operating model, the final organisation chart, and expected employee behaviours must be defined. Once defined, the leadership team can align to a common vision of its future operation and begin efforts to efficiently build its operation and the supporting organisational culture.

As emphasised in Section C, the effectiveness of your leadership team is the most significant determining factor in achieving your objectives. Who you select and how you bring them together and align their thinking, decisions, messaging and actions will largely determine your level of success.

Staffing

- Prioritise the hiring of leaders for each functional area; do not hire employees without the corresponding leaders in place.
- Build a critical mass of experienced leaders who have high aptitude skill sets in plant operation, communication, decision-making and organisational development. Caution: Operational leaders with singular experiences at well performing plants may lack the program development and implementation skills required to drive organisational progress toward operational readiness. You need leaders with significant change management expertise to build your program. Look for change agents (i.e. personnel with well exercised skills in change management).
- Design the final organisational chart required to operate the facility. Allow flexibility in the organisational steps required to achieve the desired end state over time as you progress through commissioning, FL, plant startup, and PAT to COD. Define what functions or functional support will need to be contracted.
- Consider an effort to reach out to other plants and/or WANO and invite personnel to participate in temporary assignments at your facility for one to two years. Such temporary personnel can fill gaps in knowledge and skills and help develop corrective actions for weak program areas.
- Develop a succession plan with consideration for the changes required in the organisation as you progress toward operation. Recognise the need for flexibility. Be ready and willing to move people from one role to another as your operation evolves.

Policy, Processes and Programs

- Define the operating model. Build the processes, programs and procedures needed to achieve the model. Align the leadership team around this model. Communicate the model broadly to assure clarity, create understanding, and establish alignment. Leave no doubt regarding the operating model to be used.
- Develop and implement an expectation that leadership team members spend time in the field with employees and contractors. Develop a robust program for leader time, observation, and employee interaction in the workplace. Use WANO guidance to develop this program. Implement program requirements no later than the start of HFT. Use all available opportunities to grow personnel familiarity with the plant, find and correct problems, promote employee interactions and learning, and strengthen organisational teamwork.

Procedures

Training and Qualification

- Establish the expectation that plant leaders will either have or will soon participate in SRO level training (ranging from participation in either a six-month, abbreviated management plant license training program or participation in a full two-year license training program followed by plant operations experience). Strategically plan when these individuals will exit the line function to attend this training.
- To accelerate the development of non-nuclear personnel, consider making loaned assignments to other organisations (e.g. other plants including the reference plant, IAEA, WANO) to grow operational familiarity and individual competencies. Such assignments might range from several months to several years. This in effect is also a significant bench marking opportunity.
- Once the majority of the leadership team is staffed, create and implement leadership development training to grow the leadership team competencies needed to support the operating model. This effort should also help identify and develop those leaders most critical to the current and future leadership of the station.
- If the organisation is multicultural, provide training to accelerate the understanding of cultural norms and behaviours. Take action to harness the strengths and mitigate the weaknesses of the national culture. Train leaders to be more effective communicators.

Facilities and Equipment

Building Leadership and Organisational Effectiveness

- Create an organisational culture that respects and prioritizes nuclear safety. Reinforce the need for and process of conservative decision-making. Routinely reference WANO's "Traits of a Healthy Nuclear Safety Culture."
- Build a culture of accountability. Work with the executive team to define and align to a fair and consistent model of personnel accountability. Establish HR guidance that supports the desired model of accountability. Line managers, facilitated by HR, must fairly and consistently reward, recognize, coach, counsel, discipline and terminate employees as circumstances require.
- Develop leaders that are passionate about teaching and developing employees. Create a learning organisation that embraces continuous learning and employs daily practices intended to promote growth in employee knowledge, skills and behaviours.

- Create a safety-conscious work environment. Encourage and empower employees to find, identify and help address problems and issues. Recognize and reward supporting behaviours; be cautious not to suppress the correct behaviours.21

[21] WANO PCD 2019-01 Nuclear Leadership Effectiveness Attributes

Guidance for the Nuclear Oversight (NO) Function

Nuclear Oversight (NO) provides one of the essential levels of operations performance assessment. NO is a company internal assessment function typically reporting to the Chief Nuclear Officer (CNO).

The NO organisation serves as an extension of the Chief Nuclear Officer's (CNO) eyes and ears. Observations, data and properly characterized issues and concerns provide the CNO valuable insight into the organisation's progress and performance. Well-written NO assessment reports should help direct the CNO and the operations leadership team's focus, engagement and action.

Issue identification and characterization is the true value of the NO organisation. Issues that are timely, well supported by facts, logically constructed, and properly graded by level of importance provide the operation's leadership team the opportunity to more effectively and efficiently guide the organisation toward success.

Staffing

- Design your NO organisation with a broad mix of operational expertise (e.g. engineering, maintenance, chemistry, RP, etc.). However, the strength of the team must be operations functional experience and expertise. Consider hiring a person with licensing and regulatory experience during the operational readiness phase of the project.
- Hire nuclear experienced NO evaluators familiar with industry standards of operational excellence in their areas of functional expertise.
- NO evaluators are developed based on experience in their originating core function. Very few persons spend a career in NO. Evaluator indoctrination and training for nuclear experienced personnel will likely be required.
- Hire mature NO evaluators. Evaluators should demonstrate personal maturity in the form of interpersonal skills. Evaluators must be critical without being offensive. Evaluators should be professionally mature in the form of the ability to take facts and observations and subsequently craft credible, logical conclusions.
- Consider creating a temporary rotation of personnel through the NO evaluator role – perhaps 18-month assignments. NO assignments can serve as developmental roles for future leaders.
- NO evaluator roles are a great place for new hires. New hires can add value with new and objective observations. They also benefit from learning the organisation prior to moving to an assignment in another function.
- Recognize that the skills required through construction and commissioning will be different to those skills required to provide proper oversight during plant operation
- Use short-term contracts and consultants to fill staffing gaps and/or address periods of higher levels of functional activity.
- To the extent possible for a small organisation, the NO organisation should reflect the demographics of the broader organisation. In a broad demographic environment, an assessment function of a single demographic raises the potential for animosity and ill will, and can be a negative impact on the organisation and its culture.
- Determine the role of NO personnel in support of the observation and assessment of construction activities. If desired, staff accordingly.

Policy, Processes and Programs

Procedures

- Define the hierarchy for NO procedures.
- Create a “Conduct of Nuclear Oversight” document to define and capture the fundamentals, principles, standards and expectations for strong NO performance. Use bench marks and WANO guidance to establish these standards.
- NO standards should define the proper protocol for observation and issue escalation with line management.
- Include a process for the identification of missed opportunities.
- Do not allow NO to become a repository for procedures without clear functional ownership.

Training and Qualification

- Ensure all staff are trained to WANO recognized standards.
- Become an active member and participant in the WANO INSO working group.
- Develop an initial and continuing training program. Include personnel participation in the WANO Independent Nuclear Safety Oversight (INSO) working group training program as a foundation for initial training.
- Regularly bench mark operating utilities to keep current with industry learning and trends.
- Seek out opportunities to participate in WANO member support missions at other facilities as evaluators or observers.
- Importantly, train all NO personnel on the typical findings of the IAEA and WANO during support missions, inspections and assessments.

Facilities and Equipment

Other:

- Educate the organisation to understand the concept of oversight and the role of NO. Take the opportunity to introduce the concept of defence in depth.
- Establish NO performance metrics as early as possible to measure and challenge effectiveness. A key gauge of NO performance is the number and quality of field observations. Observations should predominantly be plant walk-downs, work activities, classroom and simulator training, drills, etc. NO evaluators should be prominent in the field, not at their desks. Set a standard for time in the field and numbers of quality observations per week e.g. 50% / 5 per week.
- Engage functional line managers in accordance with defined NO protocols for the proper sharing and escalation of observations and issues. Doing so will help line managers embrace NO as helpful.
- Engage with the regulator at the earliest opportunity, demonstrating that the operating organisation has a strong internal oversight capability. This will go a long way to building regulator confidence.

- Build a relationship with other independent and external assessment agencies. Such relationships can carefully help influence more accurate external perceptions of operational readiness and performance.

- Develop and execute formal NO assessments for important second-tier milestones. Examples include: fuel receipt and readiness for HFT and associated MCR staffing by operations staff.

- Early issue identification will optimize the potential impact of NO observations and findings. Develop a formal plan for the careful observation and scrutiny of the initial (or at least early) execution of important evolutions. Within this plan, develop a comprehensive list of critical NO check points to promote early issue identification, reporting and line resolution. See a suggested list of checkpoints in the figure below. Plan to do follow up observations to verify the effectiveness of response to critical observations.

Figure E.1 Nuclear Oversight Critical Check Point Plan

NO should define a comprehensive plan for the careful scrutiny and assessment of the first execution of operational events such as the following examples:

1. Classroom instructional quality and trainee decorum for each of five core operating functions.
2. Classroom instructional quality and trainee decorum for the initial implementation training of all programs.
3. System turnover to commissioning.
4. System turnover to operation.
5. Plant evolution pre-job briefs (PJBs) by all core operating functions.
6. Chemistry sampling of all types.
7. Chemistry analysis and calculations.
8. Use of plant operating procedures.
9. Execution of commissioning tests.
10. EP exercises by each ERO team.
11. Field use of SAMG equipment.
12. Safety drills of all types (e.g. fire drills).
13. Training record completeness and quality for each of initial generic fundamentals, systems, integrated systems, and simulator segment completions.
14. Classroom examination to include first efforts to execute operator license protocols for both classroom and simulator examination.
15. Quality of early organisational meetings required by process or program (e.g. schedule review meetings).
16. Quality of early organisational critiques required by process or program (e.g. simulator training scenario critique).
17. First days of operation following initial MCR staffing.
18. Early field activities of new contractors or new contractor personnel.
19. Initial Key Performance Indicator (KPI) development and use
20. Conduct of just-in-time training and simulator use in preparation for plant tests and evolutions

To the extent possible and as deemed appropriate, NO should consider performing additional checkpoints when new personnel are executing activities for the first time to ensure consistency across personnel / organisations.

Source: New Unit Assistance Working Group

Guidance for the Nuclear Performance Improvement (NPI) Function

The principle of continuous improvement is a core industry operating principle. The NPI function has the responsibility to introduce and nurture this principle within the operations organisation. The industry has long embraced the philosophy of learning from each other. This is best illustrated by the worldwide nuclear industry's intent and efforts to learn from major events. The industry's guide entitled "The 25 Events that Shaped the Nuclear Industry" outlines the origin of many of the industry's performance techniques and the basis for these corrective actions. This guide is essential reading for the new, nuclear executive.

The cadre of continuous improvement tools, techniques and protocols are housed in the Nuclear Performance Function. Key areas include Bench marking (BM), Corrective Action Process (CAP), Operating Experience (OE), Error Prevention or Human Performance (HU), and Assessment.

The success of the NPI organisation is predicated on two things: 1. the quality and ease of use of the functional processes, programs and tools developed, and, more importantly, 2. the degree to which these tools are embraced and used by every function of the organisation.

Staffing

- Given the two NPI organisation success criteria defined above, the NPI lead role must be filled by a person with exceptional leadership skills. Not only must this person lead and manage the development and implementation of NPI process, programs and techniques, they must possess the influencing skills required to effectively educate, align and engage the entirety of the organisation in the use of NPI techniques.
- Nuclear leadership and expertise are especially critical in the areas of CAP and HU.

Policy, Processes and Programs

- BM: There will be significant desire for bench marking other organisations with strengths in various functional areas. While highly beneficial, there is a cost. Optimize the return of investment of all bench marking activities with the disciplined use of a well-defined BM program. This program should require formal BM trip planning, the reporting and documentation of findings, a review process, and the responsibility of participating personnel to initiate improvement actions to help ensure the wise use of company resources.
- CAP: There is a range of important metrics that help monitor and assess CAP performance. You will need to guide the organisation through steps of CAP performance improvement. Follow the proven sequence of metric improvement as follows: 1. Number of CAP submissions, 2. CAP overdue corrective actions, 3. Number of CAP extensions, and 4. Quality of CAP effectiveness reviews. These four items should be trended. Where adverse trends exist, corrective action should be initiated.
- OE: There are variety of OE sources of information available to your organisation. The IAEA and WANO are examples of such sources. Use these sources. Take efforts to ensure OE access and use is incorporated into other functional processes, programs and techniques. Examples include maintenance PJBs.
- Your organisation is a new source of industry operating experience. You will be expected to share your issues and events openly. NPI should prepare to fulfil this responsibility to the industry for your organisation.

- HU: The biggest impact to safety performance is plant or organisational events. To avoid events, you must minimize the potential human errors. The HU program is designed to do just that. See HU program basics provided at the end of the NPI functional section.

- Assessment: Carefully determine the scope and timing of planned organisational assessments. Minimize the scope to those assessments that can truly add value.

Procedures

- Create (based on recognized industry bench marks of excellence) a “Conduct of NPI” document defining the majority of NPI protocols and standards. Consider developing a more detailed or specific set of behavioural expectations such as a fundamental expectations document for NPI personnel.

- Do not start program development from scratch. NPI programs are well defined and developed in many nuclear organisations. Carefully select locations with strong NPI programs that are effectively executed and bench mark these programs.

Training & Qualification

- Plan to develop HU and root cause analysis (RCA) capability as an area of strength within the operations organisation. Growing organisational expertise, capability and capacity in these areas is a low-cost, high-return investment you will never regret.

- The scope of implementation training for NPI programs will be very large especially for the areas of CAP and HU. Plan and schedule conservatively.

- Use the new employee onboarding process to introduce and/or train on the NPI programs and techniques.

- Minimizing the number of employee errors and eliminating events is critical to operational performance. The HU tools are a key line of defence. Thus, it is recommended that error prevention and use of the HU tools be defined as an organisational core competency for all employees in the organisation. This competency should be supported by routine training and qualification. Specifically, annual training and requalification is recommended.

- RCA is critical to the organisation’s ability to effectively respond to events when they occur. Invest in the quality training of SMEs that are designated both inside the NPI organisation and within core operating functions. Equipment RCA personnel in engineering and maintenance will need specialized technical training.

Facilities & Equipment

- Software that supports NPI functionality is important to both the effectiveness and efficiency of your NPI programs. This includes ease of use by the end users throughout the organisation. There are several exceptional, commercial software packages vetted by the nuclear industry that support the entirety of the NPI suite of functions. Do not create your own nor sign up to a bespoke model if offered by your EPC contractor.

- Given the recommendation for error prevention training and HU tool use, identify a designated training location. Equip this location for its intended purpose to include targeted content postings, lab areas, support models and simulators. Make the facility representative of the actual field environment to the greatest extent possible to optimize the learning experience.

- Introduce and reinforce the use of HU tools in other training lab and mock-up facilities to include operations simulators, maintenance mock-ups, and chemistry and RP labs.

- Create and provide a suite of complimentary NPI related tools, techniques and guides for daily use by line managers when engaging employees. Be creative.

Managing the Organisation

- As suggested by the criteria for selecting an effective leader, NPI will play a significant role in helping to form and nurture employee and contractor behaviours consistent with the organisation's defined values. Examples include: 1. Building a high personal accountability culture in the pursuit of achieving zero CAP overdue items. 2. Educating executives, managers and employees on the requirements and benefits of reporting events quickly and factually (i.e. demonstrating transparency).

- The CAP program will likely span both the construction and operational activities. Start this effort early to help obtain construction organisation support and to ensure that operational requirements are not unnecessarily onerous on the construction effort.

- Engage your CNO early to establish him as a champion of both the CAP and HU programs. At a minimum, routine review of daily CAP items can provide needed insight into organisational needs and issues. In addition, chairmanship of some form of HU forum will help guide program development, promote HU tool use, and assist in the pursuit of error-free operation.

- Engage HR in establishing the complimentary means of event investigation and associated corrective actions. HR and NPI processes must be compatible, complimentary and timely to ensure: 1. needed event corrective actions help strengthen performance and underlying elements of the operation model, and 2. needed personnel actions are in accordance with policy and are fairly and consistently applied.[22]

The Basics of Managing Human Performance (HU)

The Objective: Achieve event-free plant operation. This objective includes the elimination of all types of plant events in the areas of nuclear, industrial, radiological and environmental safety and security.

Key HU Principles:

- People are fallible; even the best people make mistakes (errors).

- Organisational values and processes influence individual behaviours.

- Error-likely situations are predictable, manageable and preventable.

- People achieve high levels of performance based largely on the encouragement and reinforcement, or coaching, received from leaders, peers and colleagues.

- Events can be avoided by understanding the reasons why mistakes occur and applying the lessons learned from past events.

- Employees can avoid an error-likely situation by adhering to the following expectations:

[22] WANO GL 2010-01 Guidelines for Performance Improvement at Nuclear Power Plant, and WANO GL2001-07 Principles for Effective Self-Assessment and Corrective Action Programmes

- Maintain situational awareness of plant surroundings and operational circumstances.
- Stay focused on work tasks by practicing the STAR technique - Stop, Think, Act and Review.
- Think critically. Have a questioning attitude.
- Stop a task when unsure.

- Employees can minimize the potential of an error occurring when performing a required work task by using the following techniques, the HU tools.

There are 13 prescribed HU field worker tools designed for use when preparing for, executing or reviewing plant component manipulations or work tasks.

1. Procedure Adherence: the industry uses procedures to perform work tasks and follows them verbatim.
2. Place Keeping: a technique for ensuring a procedure is followed as written.
3. 3-way Communication: a technique used to ensure accurate communication when providing direction and sharing critical information.
4. Phonetic Alphabet: the use of a standard word set that represents each letter of the alphabet with the intent of providing verbal clarity (especially for letters with common sounds).
5. Self-Check: the deliberate use of STAR when conducting a plant component manipulation. It is often described in practice by point, touch, verbalize.
6. Independent Verification (IV): the check of a previously performed plant action to ensure the intended outcome was achieved.
7. Concurrent Verification (CV): the independent determination of an action yet to be taken that ensures the planned action is correct.
8. Peer Check: collaboration with a qualified colleague to check the accuracy of a planned action.
9. Flagging: the temporary tagging of a component during a work task to help guide workers when preparing to operate and/or returning to a component after task disruption.
10. Pre-Job Brief (PJB): the thoughtful and deliberate review of job responsibilities and planned work actions prior to the start of a work task.
11. Job Site Review: the use of two minutes to carefully inspect a work site and identify and correct or remove hazards prior to the commencement of work.
12. Turnovers: the thoughtful and deliberate process of handing over a work assignment to a fellow worker(s) prior to task completion.
13. Post Job Review: the thoughtful and deliberate review of completed work to identify, capture and report issues and lessons learned with the intent to improve the effectiveness and efficiency of future job performance.

There are three prescribed HU knowledge worker tools designed for use when preparing for, executing or reviewing plant component manipulations or work tasks.

1. Validate Assumptions: the practice of checking to ensure that prerequisite conditions have been met. This practice requires some form or deliberate and/or physical assurance.
2. Peer Review: the practice of engaging a qualified colleague to conduct a work product review and provide critical and constructive comments on quality.
3. Independent Determination: a parallel check to verify accurate data management and/or calculation(s).

Guidance for the Nuclear Risk Management (NRM) Function

This function creates and maintains the Probabilistic Risk Assessment (PRA) model which provides underlying support for the plant's design basis and beyond design basis.

The PRA model will include internal and external events in all plant operational modes for level 1 (core damage) and level 2 (containment failure). The challenge to developing a full scope, high-quality PRA model is significant, especially for fire, flooding and seismic models with multi-unit impact. A high-quality PRA model will provide critical support to the process of engineering design changes, configuration risk management, support for management risk-informed decision-making and future changes to the operating license, and plant risk-informed applications.

The NRM function must address beyond design basis accidents that were not previously contemplated or fully considered in the original design. PRA insights will help you address beyond design basis accidents. You will find that beyond design basis events and severe accidents are the major contributors to core damage frequency (CDF) and large release frequency events. The contribution is much higher than that incurred by design bases accidents.

Staffing

- Hire a PRA manager with both excellent technical and leadership skills. PRA technical knowledge should include model development and the use of risk-informed applications. Ideally, this individual should have plant specific knowledge in the areas of operation, engineering and maintenance.
- Given the significance of new plant PRA challenges, hire a selection of PRA experts whose collective knowledge encompasses the areas of fire, seismic, flooding, station blackout, common cause failure (CCF), and human reliability analysis (HRA). These personnel will need solid plant operational knowledge to include operation (e.g. EOP, AOP and SAMG), engineering (e.g. system, program, design, etc.) and maintenance (e.g. work management for both online and outage, maintenance rule, etc.).
- Regulatory requirements for PRA are very different from country to country. Thus, PRA engineers from different countries will have widely varying skill sets. E.g. an individual may have specific plant design knowledge and PRA model development skills, but lack experience in the use of PRA application tools and techniques. Often, U.S. trained personnel will have a more complete set of PRA skills given their experience managing risk using the informed regulation required by the U.S. Nuclear Regulatory Commission (NRC) over the past 20 years.
- Hire team players. A team of PRA experts that can work effectively together is critical for the efficient development of a quality PRA model and the use of PRA applications.

Policy, Processes and Programs

- Begin PRA modelling at the initial plant design phase. Risk insights from the PRA study for beyond design basis events, severe accident, CCF and HRA should be considered and resolved in this phase. Doing so can significantly improve plant safety.
- Plan to provide PRA support for security in the areas of target set analysis and cyberattack assessment.
- Ensure the operating license allows for the use of the following PRA applications: risk-informed ISI, IST, TS LCO, etc. Learn how to use these applications to reduce operating costs and improve plant safety.

- Use of PRA applications often require implementation across multiple disciplines. Engage the leadership team to help promote teamwork and effectively implement the output of these applications.

Procedures

- Develop and implement the following scope of NRM/PRA model documents:
    - PRA model maintenance and update.
    - PRA engineer qualification.
    - Risk-informed configuration risk management for all operational modes: online, low power and outage. Focus on the interface with operations and work management (WM).
    - Procedures for specific PRA applications such as in-service inspection (ISI), in-service test (IST), allowable operating time (AOT) extension, risk-informed technical specification changes, trainings (ops, engineering, etc.), 10CFR50.69 (graded QA), beyond design basis, and severe accident management, EP support (especially for multi-unit events), security target set analysis, cyberattack risk assessment, and aging management.
- Verify that procedures for plant design changes, risk- informed decision-making processes, and maintenance rule identify PRA interface requirements.

Training and Qualification

- Enrol and participate in the EPRI training program on PRA fundamentals. This training includes six high-quality training modules.
- Enrol and participate in EPRI and Owners Group provided training on specific aspects of PRA modelling to include Fire PRA, Seismic PRA, HRA, and CCF.
- Enrol and participate in EPRI and Owners Group provided training PRA applications
- Define PRA engineer qualification requirements using industry standards enhanced with specific plant requirements. Create and use a formal qualification card to track employee development progress.
- The PRA is a dynamic model that provides operating insights during all modes of plant operation in both normal and emergency conditions. Teach the organisation how to use PRA insights during plant decision-making. This practice is referred to as risk-informed decision-making.

Facilities and Equipment

- The PRA program will require PRA management software and application tools.
- PRA software and tools should be classified properly. They are not safety related in general, but do need software QA certification.

Guidance for the Operations Function

Operations is one of six core operating functions. A core operating function distinguishes itself from other functions as follows:

1. The function has defined principles and standards of conduct based on industry experience.
2. Functional personnel must demonstrate requisite knowledge, skills and behaviours (i.e. fundamentals).
3. Functional personnel have the highest level of direct impact on day-to-day operational decision-making and plant manipulation.
4. The functions are supported by rigorous initial and continuing training programs. The supporting training programs are based on a formal systematic approach.
5. The functions are the focus of both internal organisational performance oversight and external assessment and evaluation (e.g. WANO).

The six core operating functions are chemistry, engineering (including reactor engineering), maintenance, operations and radiological protection. Subject to effective leadership, strength in plant performance is directly dependent on the capability and capacity of personnel in these six functions.

Staffing

- Establish executive alignment around the importance of the pipeline of operators as the basis for long-term development, succession planning, and strong site operations leadership (i.e., early establishment of an operations-led organisation).
- Define a robust MCR staffing structure that includes a shift manager position. Hire experienced, previously licensed personnel to fill these positions. At ECD, begin hiring operations and operations training staff to support and participate in license training.
- Hire high-calibre personnel with proven maturity. Hire 200% of targeted license output. This includes former licensed personnel with the same or similar technology, and other non-nuclear personnel familiar with grid/switchyard interconnection requirements of the relevant jurisdiction.
- Be cautious not to paint too optimistic a picture of the training pipeline. The first time through will be fraught with surprises and trainee/trainer frustrations. Make conservative assumptions about first time pass rates. Expect a training failure rate of 50%.
- Managing the staffing numbers of licensed personnel is difficult, especially for multi-unit sites. Trainee hiring rates, training pass rates, personnel attrition and personnel promotions combine to create a challenging puzzle for operations management. Develop (or purchase) a software tool for managing the number of trainees in the license training pipeline. Ideally, obtain a software tool that has been used and is well-tested.
- Include the use of a comprehensive set of screening and selection tools to ensure physical, mental and emotional aptitude of potential new hires. Do not hire operations personnel who cannot meet future medical requirements for license, on-shift fire response, or radiation worker qualification.

- Hire operations experienced personnel to serve as mentors. Develop and implement mentor role guidance. Provide operations trainees in pipeline with supervision, training support and parenting. To enhance mentor support, include previously licensed personnel as part of the license class, and pair them with inexperienced personnel new to nuclear.
- Field operators are critical hires for the operations shift organisation. Field operators typically serve as feeder stock for future license classes. Ideally, select and train field operator candidates with the academic competencies required to support participation in future license classes. Oil, gas and chemical plant operations have typically proven a good source for plant field operator hiring.

Policy, Processes and Programs

- Operations processes and programs that support configuration control are critically important to safe plant operation. Bench mark these areas carefully and develop high-quality procedures.
- Clearance and Tagging (C&T): Ensure federal and local requirements are considered, as well as nuclear industry best practices. Purchase and implement a supporting C&T software program that supports these standards and practices. The capability of the C&T program is not only critical to personnel safety and equipment protection, but is also an enabler for efficient plant operation.
- Establish a protocol and supporting standards for establishing protected pathways. The use of protected pathways is a means of surrounding critical plant equipment with formal, robust barriers and access controls to ensure safe and continuous operating and/or standby functionality.

Procedures

- Create a “Conduct of Operations” document defining the majority of operations protocols, standards and expectations. Do this referencing recognized industry bench marks for operational excellence identified by WANO. Consider developing a more detailed or specific set of behavioural expectations such as a fundamental expectations document for operations personnel. Regularly discuss the proper application of these principles as the plant progresses from construction through commissioning and on to operation.
- Create all required simulator procedures prior to training lesson plan development in support of integrated systems training, and, most importantly, simulator training. Designate these procedures as for training use.
- Define and implement your HU tools and drill your operators in training to gain proficiency. Do this prior to simulator training. Make HU tool use a habit from the start of practical training.
- If being used, define the means and expectations for the application of HU tools in computer-based procedures.
- Verify you have the bases documents for operation procedures (especially for off-normal, emergency procedure, and beyond design basis accident guidance) and associated training materials development. This is critical to train operators on the basis for their action (i.e. why something is accomplished).
- Determine a means of producing user-friendly, paper-based backups for computer-based procedures. In the event of a loss of MCR computer-based procedures, operators must be able

to efficiently navigate these documents. A different format is likely required. Lack of forethought can create long, inefficient and difficult to use procedures for the operators.

- If possible, consider the development and use of symptom-based procedures for the management of emergency procedures.

Training and Qualification

- Define and reinforce standards of nuclear professionalism right from the start.
- Define standards of academic integrity. Put in robust barriers for monitoring and verifying operations integrity during test taking. It is important to note that differing cultures have differing assumptions and expectations that may not be readily apparent to all.
- Develop standards for the conduct and oversight of simulator training. Familiarize and align classroom and simulator instructors and operations leadership personnel to these standards. Operations leadership must take responsibility for the quality of operations training being delivered from the very beginning.
- Develop a regimen of formal operations crew performance tests to be used internally. Develop these tests with growing levels of scenario difficulty and multiple plant failures. Conduct these repeatedly, over time for all crews prior to evaluation by WANO during the PSUR. Use veteran, external assessors to help provide independent reviews of your operator and crew performance. Satisfy yourself that your operators and crews can safely operate the plant and proficiently address abnormal plant conditions before inviting WANO to assess operations crew performance.
- Build an operations training program using a rigorous, systematic approach. Consider and apply varied learning methodologies.
- Develop an examination based on international standards, but consider local culture and the regulator’s philosophy.
- If an operations program is established that sends trainees to other operating licensed facilities to observe actual plant operations (e.g. plant reactivity manipulations), establish a formal program to record and document these activities and the associated hours spent on shift. Establish formal guidelines and expectations for trainee participants and operations oversight personnel. This is especially important if this program is part of the regulatory basis for licensing personnel.

Facilities and Equipment: Simulator

- Consider building inexpensive, partial-scope simulators to enhance scope and quality of the training experience and help prevent simulator limitations to pipeline throughput (See Success Stories in Appendix 5).
- Take steps to maintain simulator configuration in parallel with plant design changes. Establish and maintain simulator fidelity, or the mirroring of all aspects of plant main control room design and operation.

Commissioning support

- Implement nuclear professional standards in the MCR (allowing for some construction structural limitations) prior to the conduct of HFT activities.

- Staff the control room with trained (not necessarily licensed) operators to support the conduct of CFT and HFT. This provides manpower support and tremendous learning for future operators.

Other

- For multi-unit facilities, conduct regular operations peer meetings to help create and reinforce the use of common governance standards across all operating units. This should include requirements for process and program use, definition of plant operating standards of excellence, and adherence to behavioural expectations, all of which should be captured within the “Conduct of Operations.”23

[23] WANO GL2016-01 Conduct of Operations at Nuclear Power Plants
WANO GL2016-02 Operations Fundamentals at Nuclear Power Plants,
WANO GL2001-04 Guidelines for Plant Status and Configuration Control at Nuclear Power Plants,

Guidance for the Organisational Effectiveness (OR) Function

The objective of the OR function is to, in fact, enhance the effectiveness of the organisation and its leaders. By doing so, it works to improve organisational performance. The function focuses on creating the following:

- Individual responsibility and accountability from top to bottom of the organisation.
- Effective two-way communications with management and throughout the organisation.
- Organisational understanding and alignment to priorities, objectives and expectations.
- Organisational integration both vertically and horizontally. Ensuring leadership team accessibility, promoting transparency, and preventing the formation of silos, or areas of isolation, within the organisation.
- Cooperation and teamwork within and across all organisational boundaries.
- Trust in leadership and between all entities.

The above organisational attributes are essential to creating a strong operating capability and a healthy safety culture. Thus, the OR function plays a critical role in promoting safe and efficient plant operation. What makes the OR challenge particularly hard is that the new unit organisation will be rapidly growing, and the culture will be constantly evolving. Your organisation will be a moving target. This challenge will necessitate that OR function personnel establish and implement a systematic approach to the creation of these organisational attributes. This approach must include a constant effort to survey, assess, adjust and take action to improve organisational practices, behaviours and culture.

Before proceeding, be sure to take note of two special topics provided in Section H of the roadmap. These two important topics: The Challenge and Opportunity of Multiculturalism AND Plant Operations in Multilingual Environments. Do recognize that new nuclear entrant countries are highly likely to be multicultural.

Staffing

- The size of the OR function is a direct function of the complexity of your organisation and the challenges it faces. Higher numbers of OR personnel should be considered as one or more of the following organisational complexities exist:
    - New Organisations - especially those in new nuclear host countries with limited infrastructure.
    - Organisations facing rapid growth or change.
    - Unique and complex organisation and/or contractual arrangements.
    - Existence of unusual or significant political or union structures, forces and activities.
    - Existence of unique and significant technical or operational challenges.
    - The demographic distribution (i.e. spread or concentration) in your staff (age or gender).
    - The distribution (i.e. spread or concentration) in your staff of technical expertise.
    - Extent of multiculturalism.

- Extent of multilingualism.

- Given the nature of complexities listed above, consider the need for specialty skill sets to include language or cultural specialists, executive coaches, facilitators, psychologists, etc.

- Given the size and duration of the complexities listed above, plan to grow or shrink your organisation where and when needed to address the extent of your plant challenges.

Policy, Processes and Programs

New Nuclear Entrants

- As part of the exercise to define your operating model, create a clear vision of how you plan to lead and manage your organisation. Define the desired culture, leadership style and personnel behaviours. To do so, ask and then answer important questions such as the following:
    - What must we do to create a healthy safety culture?
    - What does industry experience tell us about being a strong operator?
    - What unique challenges will we face?
    - What will be the demographics of our organisation?
    - What are the strengths and weaknesses of the host national culture?
    - What language will we operate in?
    - What leadership style do we need to adopt?

The organisation will benefit from the degree to which you can describe your vision. Determine corporate values and desired behaviours that align with your chosen style

- Building a healthy nuclear safety culture will require the development and implementation of a systematic approach. This approach must include the definition of organisational values and expectations, constant engagement and communication by numerous and various means. In addition, it should include the teaching of the basics of plant operation as well as the bases for plant practices, processes and programs. Remember, your organisation is growing and changing rapidly. This will necessitate that you repeat actions, provide explanations, and reinforce standards and expectations constantly to achieve the cultural development required.

- Compare your intended organisational approach to that of your key stakeholders (owners, partners, contractors, regulators, IAEA, WANO, etc.). Identify where contrasts in styles and approaches may cause major issues. Issues with alignment, assumptions, communications and engagement styles can lead to confusion, ineffectiveness, conflict, rework and ultimately project delays and increased cost. There will always be some measure of misalignment. Ensure that an operating model is created and promoted that all stakeholders can commit to delivering.

- Create and then continuously communicate and align processes and programs to the articulated shared vision of the operating model (i.e. how we will operate. Refer to Section C regarding the operating model). The organisation will rapidly grow and develop towards fuel load. For new nuclear entrant countries, this includes your regulator. Newly hired employees with nuclear experience will bring great and varied experiences from across the world – these employees with their individual perspectives on how it should be done will need to be aligned to a shared vision. New inexperienced employees will bring questions, concerns, energy and untapped potential – these employees will need to be educated on the vision and the bases of each aspect of the vision. In all cases, continuously communicate the shared vision. Ensure both leaders and workers are creating the policies, processes, programs, procedures and behavioural expectations that help develop people in a way that aligns to the shared vision.

- Support those who are new to nuclear. For previously non-nuclear staff, nuclear operation is an abstract concept. This group will struggle with having an integrated picture of how everything fits together. The greatest challenge can be when new to nuclear staff are in leadership positions. This can lead to misalignment to the overall strategy or goal, as well as misalignment in work groups. This can manifest itself in, well intended, but misaligned policies, processes, programs, procedures and supporting behaviours. The higher the new to nuclear complement in the workforce, the more constant and consistent communications needs to be regarding your operating model (i.e. how we will do things.).

- New projects find that employees who can readily adapt and then apply the lessons and skills of their past experiences are the most successful. Some employees become fixed on how they used to do things and find it difficult to adapt to new processes and programs, as well as the new culture. The most successful employees and leaders are able to deconstruct their experiences, understand what worked and why, and then create robust practices that work in the new environment. This creativity is not a skill often exercised in nuclear, where the focus is on following the set path, or disciplined way of working. Some individuals will struggle mightily with the lack of structure and processes inherent to a rapidly changing new build environment as well as the multicultural landscape to be navigated, where there may be very different ideas on how we should do things.

- Nuclear professional behaviours need to be defined, promoted, embraced and embedded early in the journey to operational readiness. Embrace the need for establishing a nuclear safety culture early. Ensure that organisational values are defined and that expected behaviours are defined, explained, reinforced and routinely assessed and reinforced. Doing so will promote organisational alignment.

- Establish a full-time team to deliver effective and efficient organisation and staff planning. New builds rapidly grow and the organisation chart, and manpower processes, need to support this growth. If this is not done, roles and responsibilities can become unclear, decision-making can be slow, and some leaders can become overloaded by the volume of staff reporting to them until the next revision of the organisation chart is produced. Poor staff planning can affect trust in the organisation and creates uncertainty, impacting overall organisational effectiveness and the safety culture.

- Balance the work targeted for operational readiness for fuel load with that work required to build a longer term, sustainable organisation for future operation. Both are important and need to be completed. Clearly define what needs to be done for meeting fuel load and subsequent plant operation, and then again what is essential for long-term organisational success. Ensure this is communicated and understood by all staff. The workforce can become paralyzed by the volume as well as the breadth of things that they perceive need to be done. Regardless, let your schedule help clarify and coordinate the entirety of your effort.

- New nuclear countries may need to create extensive capacity building programs responsible for developing the local workforce. Involve the developing staff in decision-making. Ensure your organisation builds in sufficient capacity to appropriately support, mentor and coach new nuclear personnel. Determine the target ratio of dedicated nuclear experienced personnel to that of the local developmental workforce (a 1 to 10 ratio is recommended). Without dedicated mentors, new personnel learning may suffer as the drive to fuel load accelerates and experienced nuclear personnel are drawn to operational activities and away from developing, local nuclear personnel.

- If hiring large numbers of expatriates, establish the infrastructure to fully support them in your business. Many may bring their spouse and children, pets and household furniture with them. If the company does not establish infrastructure to support them, expatriates can become distracted as they try to navigate through settling their family into the new environment. Ensure the program includes recruitment and relocation, onboarding, housing, schooling of children and other ongoing considerations.

- For core plant functions such as operations, ensure you hire individuals that will stay well beyond Fuel load. Experienced expats towards the end of their career (55+) may be easier to hire, but they may not stay long. In operations the time required to qualify and train individuals will need to be taken into consideration. Mid-career individuals (35-45) offer stability and support retention of organisational knowledge in technical areas through startup and beyond. To attract this particular population of expatriates ensue you have robust HR processes to support relocation of families with school age children.

- Develop a systematic program to ensure the new to nuclear workforce is proficient before fuel load. This goes beyond training and qualification. On-the-job training and mentoring, as well as developing the desired behaviours, needs to be systematically developed across the site.

- Bench mark safety critical companies in the host country, such as the oil & gas, medical and aviation industries. These companies will have employees from the local workforce, and will understand the cultural norms and have a good understanding of the processes and practices that work in the country. The functions of OR, NPI, training, HR and communications will particularly benefit from such efforts.

Facilities and Equipment

- Where specialty OR functionality is required, consider what accommodating infrastructure may be needed. One example of this can be found in the special topics section of the roadmap entitled, Plant Operations in a Multilingual Environment.

Guidance for the Plant Projects Function

The plant projects function is that part of the organisation responsible for the initiation, scheduling, planning, and execution of facility and plant projects after the completion of plant construction and commissioning activities.

Staffing

- Hire nuclear experienced project managers for plant projects.
- Hire experienced, local project managers for site infrastructure projects.

Policy, Processes and Programs

- Understand the operating model requirements for project management and the intended organisational structure.
- Carefully define the difference between physical plant and site infrastructure projects and the scope of the organisation's operational readiness projects.
- Identify the scope of process and program documents needed to address all aspects of project scope determination, approval, scheduling, planning, execution and closeout. Develop these using a top-down approach.
- Integrate processes at the task level. Engage SME to create detailed flow charts and identify links between cross functional processes.
- Define expectations for formal, cross-functional communication related to plant design and project changes to help ensure efficiency and effectiveness.
- Establish clear governance and scope for the functioning and interaction of project and budget review boards and their role in approving and funding projects.

Training and Qualification

- Define the desired level of project management certification required.

Projects and Project Backlog

- Develop and implement a common classification and prioritization system for site and plant projects to allow projects of different types to be compared and impartially compete for limited resources and budget.
- Define the opportunities for operational projects post construction (e.g. projects to be performed online or during the planned warranty outage post power ascension, the first refuel outage, second refuel outage, etc.).
- Define the division of plant project responsibility between the construction organisation and the operating organisation and how this will evolve over time. Create and implement a transition plan as the plant approaches fuel load and operation. Create a forum between construction and operations executives to discuss and determine the scope of construction and operations-related site and plant projects.
- Recognize that organisational effort during project construction and commissioning phase is strictly focused on completing the plants as designed. Only those additional projects required to address critical plant performance and/or design issues will be embraced by construction. Avoid

projects not related to starting the plants or ensuring sufficient facilities, unless there is a clear, strategic business objective associated with it and full organisation backing. Otherwise, the projects will be viewed as unnecessary and will not progress efficiently.

- Create a rolling 10-year project plan to begin after startup. Identify the scope and schedule for operations projects.

Site Infrastructure

- Ideally, the plan for site layout and facilities need to be reviewed and agreed to by the owner and operator prior to completion of the site design. Requirements should be either incorporated into the EPC contract or clearly retained for execution by the owner.

- The plan for site infrastructure needs to meet operational needs. Special review and consideration should be given to the site and plant requirements for:

  - Outage preparation and execution support within the plant protected area.

  - Procurement warehousing and supply accommodations for spare parts and consumables.

  - Fire house and response capability within the protected area.

  - Plant facilities in support of EP program and the emergency response organisation (ERO).

  - Plant internal accommodation for the outage control centre (OCC) and maintenance workshops.

  - Laboratory areas.

  - Radioactive waste handling facilities.

  - Office and meeting areas.

  - Personnel clothing change and shower areas.

  - Work area embedded training facilities and accommodations.

Guidance for the Procurement and Supply Chain Function

Procurement, typically a corporate function, is one of *four key enabling support functions that will largely determine the efficiency and effectiveness of the organisation. Any one of these four support functions can work to help to accelerate or restrain the growth in operations capacity and capability development. Establishing a strong procurement and supply chain function is thus critical to organisational success.

A proper procurement function should empower line managers to do their job. Policies should be designed to make things happen, not prevent them. Procurement personnel should focus on their customers and adopt a mind-set of “how can we help line managers get things done?” Respect for policy and the procurement processes are required, but procurement personnel should not be policemen. Procurement should tolerate mistakes. When they are made, properly assess, analyse and take corrective actions to help prevent recurrence. Coach line managers as required to change future behaviours. Without a proper level of fault tolerance, organisation progress will be slow and frustrating. It is not hard to figure out that the cost of a few mistakes is hugely outweighed by any delay to the project.

*The four key enabling support functions are human resources, procurement, IT and finance. A litmus test question for each of these functions as they establish their structures, policies and procedures should be, “Are we making it easier for operations to perform their roles safely and efficiently?”

Staffing

- Hire a nuclear-experienced, commercial executive at or before the EPC contract strategy phase. This can help preclude problems during the procurement process for operational readiness support that includes:
    - Late start of critical operational contract negotiations.
    - Loss of commercial leverage due to potential single source negotiations.
    - Ineffective or randomly defined, haphazard procurement tactics.
    - Costly secondment of above current market rate consultants.
    - Inadequate scoping and delivery of operational spare parts.
    - Delays in building a suitable, operationally ready warehouse.
    - Delay in building a list of qualified nuclear suppliers and establishing blanket contracts for materials and services as required
- Establish executive alignment and support for hiring a nuclear-experienced procurement leadership team.
- Define an organisational structure for the procurement function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel with varied backgrounds. Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.

Policy, Processes and Programs

- Define and implement a “Procurement Policy” document defining the applicable standards of business ethics, personal integrity and accountability, and the consequence of noncompliance based on recognized bench marks of excellence.
- Define procurement roles and responsibilities as follows:
  - The negotiation, execution and management of all contracts.
  - The procurement of all staff augmentation efforts, to include engagement and onboarding of seconded employees, contractors and staff services suppliers. Spend time gaining agreement and support for this from HR. Employee compensation and contractor rate requirements are different and should be kept separate to optimize the cost of operational activities.
- Based on nuclear bench marks, establish delegation of financial authority consistent with nuclear industry standards for safety, quality, schedule and cost.
- Define and implement a rigorous technical and commercial project review process with three phases:
  - The development of an integrated technical/commercial procurement strategy and business case.
  - The development of both technical evaluation criteria and commercial evaluation criteria and negotiation strategy.
  - Bid solicitation, assessment, recommendation and approval for contract award.
  - Specify the time for completion of each phase. Monitor organisational performance against these expectations.
- Establish, document, and implement policy, process, and program guidelines and support systems, performance metrics and indicators, and service level agreements prior to the bulk of procurement activity. Performing procurement in parallel with procedure development can result in significant process delays, noncompliance problems and potential ethics violations.
- Integrate procurement into the work management process.

Procedures

- Develop and implement mentor role guidance applicable to those individuals responsible for developing personnel in the areas of strategic sourcing/contract management, tactical procurement, procurement engineering, and warehouse and logistics.

Training and Qualification

- Define and reinforce standards of nuclear professionalism from the beginning.
- Train and develop inexperienced staff using a structured approach (e.g. use of qualification cards). As required, deliberately develop inexperienced talent and integrate them into the organisation.

- Use nuclear experienced procurement personnel to serve as mentors; develop and implement mentor role guidance. Provide trainees with supervision and on-the-job training support.
- Monitor employee performance. Reinforce positive behaviours and performance; address deficiencies. Swiftly deal with business ethics and noncompliance issues. Incorporate observations into the formal employee appraisal process.

Facilities and Equipment

- Without delay, assess, select, procure and implement an enterprise resource program (ERP) system in support of HR, finance and procurement.
- Define the specifications for and build an operational warehouse. Carefully consider and make allowances for the impact of local environmental and logistic support requirements. Make allowances for receipt inspection, multi-mode logistics, customs, vehicles, forklifts, storage racks, and measuring and test equipment.

Other

- Demonstrate full procurement and supply force capability six months prior to FL.
- Demonstrate operational readiness with practical operational readiness exercises. Examples include:
    - Initiation of an emergent material work request.
    - The selection (or pick), staging, issuance and transport of parts and materials to the maintenance job site.
- Take extra effort to verify the availability and adequacy of spare parts needed to support critical plant tests, work activities and milestones.

Guidance for the Program Management Function

As discussed in Section D.4, the program management organisation (PMO) plays a key role in facilitating the organisation toward operational readiness. Once defined, the PMO will work with the organisation to define those projects and activities needed to build the operating model, staff and train the organisation, and create an operating culture. The entire scope of these projects and activities will be captured in the schedule. The PMO will facilitate the leadership team's effort to drive schedule execution toward operational readiness and the achievement of safe and efficient operation.

As progress toward operational readiness is achieved, the PMO organisation evolves into a smaller organisation focused on business planning and execution.

Staffing

- Hire a leader for the PMO organisation who is familiar with nuclear power plant operation, including knowledge and understanding of an operating model and an operations organisational structure. The organisation will rely on this person to act as a navigator. He or she must clearly understand where the organisation needs to go and appreciate the path and time frame for achieving operational readiness. This person must provide the CNO and other members of the executive team an accurate assessment of progress and concerns.

- Define an organisational structure for the PMO function. Include the following four key positions:

    1. A master scheduler (See Section D).
    2. An operating license project lead.
    3. An enterprise resource planning software systems application lead.
    4. A significant operating experience report (SOER) recommendation implementation project lead.

Later, consider the hiring or assigning of a person to lead and coordinate the planning, scheduling, preparation and execution of the major assessment activities tied to the IAEA pre-OSART and the WANO PSUR assessments (Refer to the assessment preparation timeline provided in Section F.4 of the roadmap).

- Pursue the hiring of project managers with both project management skills/certification and nuclear experience. Hire personnel with backgrounds in both nuclear construction and operations. Leverage experienced personnel to help define process and program standards.

- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.

- Use contracted project managers where required to accelerate progress.

Policy, Processes and Programs

- A key enabler for the PMO is to understand the definition and details of operational readiness (i.e. what does it mean?). To define and facilitate the journey to operational readiness, the PMO must understand the leadership team's vision of the entirety of its operating model, the final organisation chart, and expected employee behaviours. Once defined, the PMO is responsible for supporting the leadership team's efforts to efficiently build the operation and its organisational culture.

- Define and implement a consistent approach to the management of scope, schedule, resources and risk. Address such things as the standards for:
  - Work breakdown structure (WBS) (i.e. how works tasks are broken down).
  - The use of a deterministic versus probabilistic approach to schedule projections (i.e. the mathematical approach applied to project the range of schedule completion dates for a large scope of integrated activities).
  - The requirements and process for controlling schedule changes.
- Develop a risk register to list, characterize and manage organisational risk issues. Refer to WANO SOER 2015-2, Risk Management Challenges to define and implement an approach to Enterprise Risk Management (ERM). Embed aspects of this approach into the planning, scheduling, execution and oversight of all operational readiness activities.
- Define and implement the desired approach to change management. Appreciate that the entirety of the journey to operational readiness requires the application of change management techniques. Work closely with internal communications personnel to assist in and enhance change management efforts and communications. Many changes fail or take far longer than necessary due to poor change management.
- Develop and implement a business continuity program in coordination with the emergency preparedness program and protocols. Leverage the capabilities of both to avoid duplication of effort and create organisational efficiencies.

Training and Qualification

- Define the desired training and certification requirements for project managers.
- Define, communicate and reinforce the behavioural standards of nuclear professionalism from the beginning.

Facilities and Equipment

- Define the suite of software tools to be used by the PMO. Specify requirements for and procure the following PMO-enabling IT software:
  - A scheduling tool (e.g. Primavera)
  - An enterprise resource management system (e.g. SAP)
  - A business planning support tool
  - A business continuity support tool (e.g. Catalyst)
  - An enterprise risk management tool (e.g. ARM)

Ideally, align this suite of software tools (including version) for use during construction, operational readiness activities, and future online and outage work management. Doing so will optimize the development of organisational competencies, thus improving staffing and succession planning flexibility and efficiency.

Guidance for the Quality Assurance (QA) Function

Staffing

- Define an organisational structure for the QA function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel. Hire personnel with backgrounds in both construction and operations. Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- QA personnel with manufacturing or supplier experience should be utilized for oversight over manufacturing at supplier facilities. Consider having continuous presence at key contractor facilities.
- Provide oversight of plant activities during commissioning by plant-experienced QA personnel.
- During the construction phase, hire people with specific experience in areas of non-destructive examination (NDE), civil and manufacturing construction activities. Deploy these personnel in the plant to provide oversight over key construction activities.

Policy, Processes and Programs

- Develop QA function processes and programs prior to process and program development by other functions. This creates the opportunity for proper QA oversight and input during these important development activities by other functions.
- Cascade QA requirements to include those for counterfeit, fraud and suspect items (CFSI) to all contractors and subcontractors.

Procedures

- Computerized procedure systems may experience implementation difficulties; write easy-to-use, backup paper-based procedures.
- Document configuration control is a challenge. Processes should be robust to ensure changes are documented and followed through.
- Identify and insert quality control, hold for inspection points within key construction work and testing activity instructions.

Training and Qualification

- In addition to QA processes, personnel should be trained in technical code requirements (e.g. ASME, ISO, IEEE, etc.). Hiring and access to in-house code experts is beneficial.
- Provide training on QA requirements to all relevant staff in other functions to ensure QA requirements are well understood.
- Train QA personnel on the findings from IAEA and WANO new unit support missions, inspections and assessments. (Refer to Appendix 1 of the roadmap).

Facilities and Equipment

- Procure surveillance tools and equipment early in the program. A post-material identification gun is an example of such a necessary tool.
- Establish either in-house capability or external service contracts with a qualified materials laboratory to support material inspection and testing activities.

Counterfeit, Fraudulent and Suspect Items (CFSI)

- CFSI has become a significant issue, with important manufacturers admitting fraudulent activities.
- Hire personnel with specific CFSI experience or provide training annually.
- Adopt the use of the EPRI CFSI checklist for all relevant functions: quality surveillance and receipt inspection, procurement, maintenance and engineering.
- Implement the CFSI program and train all contractors and subcontractors on the requirements for its use.

Guidance for the Radioactive Waste Management Function

The radioactive waste management function has the responsibility for the control, processing, handling, storage and proper disposal of low, medium and high-level radioactive waste. The function helps the organisation adhere to the principle of radwaste minimization.

Staffing

- Define an organisational structure for the radioactive waste management function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Develop and implement mentor role guidance. Provide inexperienced personnel with supervision, training support and development guidance.
- Be mindful of demographics. Hire mid-career (i.e. 10 to 15 years of experience) individuals to mitigate the gap that can develop when more senior personnel depart after the unit is online.

Guidance for the Radiological Protection (RP) Function

RP is one of five core operating functions. A core operating function distinguishes itself from other functions as follows:

1. The function has defined principles and standards of conduct based on industry experience.
2. Functional personnel must demonstrate requisite knowledge, skills and behaviours (i.e. fundamentals).
3. Functional personnel have the highest level of direct impact on day-to-day operational decision-making and plant manipulation.
4. The functions are supported by rigorous initial and continuing training programs. The supporting training programs are based on a formal, systematic approach.
5. The functions are the focus of both internal organisational performance oversight and external assessment and evaluation (e.g. WANO).

The five core operating functions are chemistry, engineering (including reactor engineering), maintenance, operations and radiological protection. Subject to effective leadership, strength in plant performance is directly dependent on the capability and capacity of personnel in these five functions.

Staffing

- Define the strategy and desired organisational approach to the execution of radiation protection practices. One key example is the decision to have workers self-perform a large scope of radiation protection activities versus the use of RP technicians to perform key support activities.
- Define an organisational structure for the RP function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel with varied backgrounds. Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Utilize capacity building programs to provide a pipeline of trained technicians.
- Use contracted, supplemental RP technician support to fill employee staffing gaps and address peak periods of needed RP support, including outage support.
- Ensure adequate proficiency in the plant operating language of choice.

Policy, Processes and Programs

- Define and document a standard for maintaining collective radiation exposure (CRE) in accordance with the RP principle for personnel dose of as low as reasonably achievable (ALARA). Define the intent to minimize plant dose areas and radioactive hot spots. Where dose sources exist, build processes, programs and personnel expectations that target minimizing stay times, increasing personnel distance, and using protective shielding.

- Define the scope of the radiation-controlled area (RCA) within your plant. Industry best practice encourages you to minimize the size of this area to the extent possible. Radioactive waste minimization and plant access efficiency are two important reasons for doing so.
- Communicate frequently with RP staff to ensure alignment and consistency with respect to conduct of RP.
- Develop and execute change management and communication plans for changes in the RP program.
- Once the RP program requirements are defined, make supporting decisions as soon as possible to include the type of protective clothing to be used, type of RP instruments to be procured, specifications for consumables, how radiological surveys will be documented and communicated to the radiation workers, practices to be used for radioactive active waste minimization, etc.
- Bench mark to seek industry best practices. Document results formally, and define the actions needed to incorporate any items that will add value to the program.

Procedures

- Create a “Conduct of Radiation Protection” document defining the majority of operations protocols, standards and expectations. Do this referencing recognized industry bench marks for radiation protection excellence identified by WANO. Consider developing a more detailed or specific set of behavioural expectations such as a fundamental expectations document for operations personnel. Regularly discuss the proper application of these principles as the plant progresses from construction through commissioning and on to operation.
- Create governing procedures using qualified personnel. Utilize independent procedure reviews to verify the scope and technical accuracy of content, and to ensure alignment with industry best practices.
- Conduct procedure reviews with new employees to identify opportunities for clarification and new ideas for more efficient ways to perform work.
- Conduct procedure reviews for drafts and revisions with an independent and qualified person who is highly knowledgeable of the subject matter.
- Conduct procedure reviews to verify regulatory compliance, technical accuracy, workability, translation accuracy and interfaces with other procedures and work groups.
- When reviewing and revising a large amount of procedures, allow enough time to ensure a quality product is produced.
- For each procedure, conduct table top exercises by a team of new and experienced personnel to ensure that the procedure can be executed as written.

Training and Qualifications

- Incorporate the principles of ALARA into classroom and practical training for all staff.
- RP technicians should be trained and qualified to the level of work that they will be performing in the field. This should be commensurate with their level of experience (e.g. ANSI standards, level of risk, etc.).

- Communicate frequently with training personnel to ensure alignment and to monitor student progress.
- Review trainee feedback on a frequent basis. Provide trainees feedback on their input to let them know that their feedback is important and that it has been acted upon.
- Require and enrol RP supervisors and staff (including supplemental workers on-site more than 6 months) in RP continuing training.
- Schedule required OJT/TPE tasks for each trainee to ensure timely completion.
- Develop progress curves to closely monitor each trainee's qualification status.

Facilities and Equipment (and Instruments)

- Prior to initial fuel on-site, designate, procure and receive the radiation protection instruments and equipment required. Use reference plant information to help with this task.
- Prior to fuel on-site, set up the dosimetry lab in support of thermo-luminescent dosimeter processing and Whole Body Counting, in accordance with accreditation standards defined within ISO Standard IEC 17025.
- Plan to begin sample counting lab operation in support of gamma-spectroscopy, liquid scintillation counting, and low background alpha-beta counting at the time of initial fuel load.

Other

- For multi-unit facilities, conduct regular RP peer meetings to help create and reinforce the use of common governance standards across all operating units. This should include requirements for process and program use, definition of plant operating standards of excellence, and adherence to behavioural expectations, all of which should be captured within the "Conduct of Radiation Protection."[24]

[24] WANO GL 2004-01 Guidelines for Radiological Protection at Nuclear Power Plants

<u>Guidance for the Reactor Engineering (RE) Function</u>

RE is one of six core operating functions. Core operating function distinguishes itself from other functions as follows:

1. The function has defined principles and standards of conduct based on industry experience.
2. Functional personnel must demonstrate requisite knowledge, skills and behaviours (i.e. fundamentals).
3. Functional personnel have the highest level of direct impact on day-to-day operational decision-making and plant manipulation.
4. The functions are supported by rigorous initial and continuing training programs. The supporting training programs are based on a formal systematic approach.
5. The functions are the focus of both internal organisational performance oversight and external assessment and evaluation (e.g. WANO).

The six core operating functions are chemistry, engineering (including reactor engineering), maintenance, operations and radiological protection. Subject to effective leadership, strength in plant operating performance is directly dependent on the capability and capacity of personnel in these six functions.

Staffing

- Define an organisational structure for the reactor engineering function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel with varied backgrounds. Leverage experienced personnel to define process and program standards.
- Hire experienced personnel (more than five years of experience) to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available. Target the hiring of some personnel with licensed operations backgrounds to assist with efforts in reactivity management and technical specification compliance.
- When manpower planning, allow two years from the hiring of a Bachelor of Science in Nuclear Engineering graduate to the completion of on-site training and qualification prior to work. Expect full proficiency to take approximately five years.
- Station reactor engineering is normally a small organisation (approximately 10 people for two-unit site). Careful manpower planning to include retention and succession management is required. Develop contingency plans to cope with unexpected manpower shortfalls.
- Maintain a pool of trained reactor engineers to cope with unexpected manpower shortfalls (e.g. trained and qualified personnel in fuels, operations, engineering or personnel serving in support functions like emergency preparedness).
- Establish and communicate a clear career path for new engineers.
- Use WANO to identify operating power plants with strong reactor engineering programs. Connect with these plants to create networks for bench marking, job shadowing, sharing of best practices, and knowledge transfer.

- Establish clear roles and responsibilities between fuels management, operations and reactor engineering personnel.

Policy, Processes and Programs

- For applicable technologies, specify, procure and implement a 3D core modelling tool. Train, qualify and gain proficiency with this important core management tool.
- Work with fuels and QA function personnel to define the role of reactor engineering in core design, safety analysis process, and fuel manufacturing surveillance.
- Conduct an independent review of core design and safety analysis to verify design integrity and ensure adequate safety margins.
- Establish procedures and protocols to protect fresh fuel from foreign material intrusion during receipt, handling, fuel pool storage and core loading. Build good practices into the maintenance foreign material exclusion (FME) program.

Procedures

- Create, based on recognized industry bench marks of excellence, a "Conduct of Reactor Engineering" document defining the majority of operations protocols and standards. Consider developing a more granular or specific set of behavioural expectations such as a fundamental expectations document for operations personnel. Regularly discuss the proper application of these principles as the plant progresses from construction through commissioning and on to operation.
- During procedure development, conduct cross discipline procedure reviews with relevant functions such as operations, engineering, maintenance and safeguards.
- Reference adherence to the maintenance FME procedure in the fuel handling and refuelling activity procedures.
- Conduct a careful validation and verification of all procedures. Repeat after the completion of applicable design changes.
- Given the number and complexity of functional interfaces with reactor engineering, consider developing a stakeholder procedure that specifies roles and responsibilities of all internal/external stakeholders.
- Create companion documents for reactor engineering procedures that define the technical bases. Describe the connection between theory and procedural practice. These documents should serve as bases for reactor engineering and operations training efforts in pursuit of personnel development and long-term knowledge retention.

Training and Qualification

- Reactivity management is a common area for improvement in WANO pre-startup reviews, and is often cited as a startup-related area for improvement (SRAFI). Take the offensive early to define and execute an effort to create excellence in this area. Do so in coordination with operations and maintenance.
- Review the operations initial and continuing training curriculum. Join targeted training sessions to enhance reactor engineer development and establish operator relationships.

- Plan and schedule the conduct of simulator training for the operating shifts.
- Prior to operation, provide training to reactor engineers and operations shift personnel on operating cycle core characteristics and reactivity management principles.
- Immediately prior to startup and power ascension, plan and provide just-in-time (JIT) training for reactor engineers and MCR operators. Use the simulator to create truer to life, practical training for participants.
- Include the loss of supporting reactor engineering software tools in training scenarios. Practice the defined operator and reactor engineer contingency actions to ensure reactor safely during loss of computerized tools.
- Perform benchmark activities at other operating plants (including reference plant). Target plants where WANO has identified a strength in the area of reactivity management. Consider arranging for job shadowing and on-the-job (OJT) training. Identify and incorporate industry best practices.
- Given the small on-site workforce and the limited body of reactor engineering expertise worldwide, establish and use a network via industrial working groups. Leverage WANO and EPRI to keep up with technical information and operating experience lessons learned.
- Take advantage of the training and learning opportunities offered by supporting vendors.
- Be active participants in the reactor engineering technical community (e.g. American Nuclear Society).

Other

- For multi-unit facilities, conduct regular reactor engineering peer meetings to help create and reinforce the use of common governance standards across all operating units. This should include requirements for process and program use, definition of plant operating standards of excellence, and adherence to behavioural expectations, all of which should be captured within the “Conduct of Reactor Engineering.”[25]

[25] WANO SOER 2007-1 on Reactivity Management

Guidance for the Safeguards Function

Staffing

- Define an organisational structure for the safeguards function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.

Policy, Processes and Programs

- Identify a comprehensive list of construction and commissioning activities requiring safeguards input against the relevant project milestones and timelines, such as license applications, receipt of export-controlled equipment, and receipt of first fuel.
- Flag any safeguards activities requiring interaction with the regulatory authority, the IAEA, or any nuclear cooperation partner (e.g. USA Title 10 of the Code for Federal Regulations).
- Engage early with the national regulator and the IAEA on the provision of facility design information.

Procedures

- Produce an overarching governance document that describes the safeguards program and the structures, systems, and components, processes, programs and procedures required for implementation.
- Align each procedure to national regulatory requirements and the IAEA safeguards agreements. The procedures should be based on the main components of regulations and agreements, including nuclear material records, reports and inventory, facility design information, international transfers of nuclear material, inspections and verification.
- Encourage peer reviews and regulatory approvals of all procedures.
- Use a company document management system to facilitate regular reviews and updates of all plans and procedures.

Training and Qualification

- Make extensive use of international assistance programs provided by the IAEA and WANO.
- Select international training courses on safeguards and nuclear material accountancy which are regularly offered by the IAEA and others.
- Constantly refer staff to IAEA guidelines and standards published in their service series. In particular "Guidance for States Implementing Comprehensive Safeguards Agreements and Additional Protocols" and "Nuclear Material Accounting Handbook."
- Align company job familiarisation guides to job descriptions for each position within the organisation chart. Monitor staff progress completing the defined requirements.

- Where possible, organise bench marking visits to safeguards departments of other operators and suppliers.

Facilities and Equipment

- Procure a nuclear material accountancy and control computer system with the capability of providing reports in the formats required by the IAEA.
- Work closely with the vendor to specify regulatory and security requirements for a system that will produce timely, accurate and auditable statutory reports, nuclear material inventory, and material/fuel history.

Other

- Request participation in any state initiative for international assessment of the safeguards program (e.g. the IAEA State System Advisory Service (ISSAS), the IAEA Integrated Nuclear Infrastructure Review (INIR), and the IAEA Milestones in the Development of a National Infrastructure for Nuclear Power).

Guidance for the Security Function

Staffing

- Define an organisational structure for the security function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Develop and implement mentor role guidance. Provide inexperienced security personnel with supervision, training support and developmental guidance.
- Be mindful of demographics. Hire mid-career (i.e. 10 to 15 years of experience) individuals to mitigate the gap that can develop when more senior personnel depart after the unit is online.

Policy, Processes and Programs

- Define the approach to fitness for duty early.
  - Establish an alcohol and drug testing approach that utilizes both for cause testing and random testing. Random testing will serve as a deterrent for personal uses of these substances.
  - Carefully bench mark the techniques for both alcohol and drug testing. Identify the most efficient process for testing to enhance the personnel testing experience.
  - Implement the program at least a year before fuel load.

Facilities and Equipment

- Train security officers in basic plant operations. Ensure security officers can identify plant systems, components and structures. Officers should understand the basics of how the components operate as well as the hazards associated with their operation.

Guidance for the Training Function

As discussed in Section D, the training function is a critical component in your efforts to create deep organisational knowledge of plant operations and foster the creation of a true learning organisation.

Staffing

- Define an organisational structure for the training function.
- Begin your staffing effort by selecting and hiring highly skilled and experienced personnel.
- Leverage experienced personnel to define process and program standards.
- Hire experienced personnel to be mentors for the development of inexperienced staff. Hire inexperienced personnel only when adequate mentoring capability is available.
- Create a supplemental force (likely contracted) of highly experienced training development and delivery personnel to help address the peak volumes of training material development and course delivery that will occur during the first 3-5 years of your program. Allow them ample time to become proficient on the power plant technology required to develop the relevant training materials for all disciplines.
- Hire technical staff (operators, engineers, specialists and technicians) and enrol them in training programs early enough to allow completion of their training and qualification prior to the start of plant commissioning activities. This affords them the opportunity to participate in all facets of commissioning and thus further their plant knowledge and understanding.
- Over hire line positions in anticipation of staff who will fail to successfully complete their training programs (success rate is highly dependent on the background/experience of the candidate). Licensed operators have higher failure rates than most other disciplines. It is not uncommon to see failure rates in excess of 50% for operator candidates who are new to nuclear.
- Evaluate the existence in your organisation of unique circumstances (e.g. language barriers).
- Anticipate the special needs that may be required due to circumstances that will challenge staffing efforts.
- Ensure line organisations demonstrate ownership of their staff's performance in training. Mentors are an effective component of managing trainee performance. Line managers should observe training regularly and provide constructive feedback to improve the overall quality of the training program.

Policy, Processes and Programs

- Define and communicate early and often the expectations of trainees while in training. See the example of 10 training expectations provided at the end of this section.
- For each functional area, identify their respective operational standards document (e.g. "Conduct of core operating function" procedures provided in appendix 2.d). Build technical training materials that reinforce these standards.
- Ensure technical procedures have supporting bases documents (especially operating procedures for abnormal conditions, emergency events, and severe accident management). These documents should form the technical basis for understanding why a procedure is written as is.

- Ensure technical procedures are accurate as early as possible.
- Ensure there is a formal process to update procedures and training materials when a modification takes place in the plant. This is especially true during plant construction when the pace of design change is high.
- Ensure training procedures are not overly complicated while still dictating training programs and processes that support industry standards and cultural norms.

Procedures

- Create a "Conduct of Training" document defining the majority of operations protocols, standards and expectations. Do this referencing recognized industry bench marks for training excellence identified by WANO. Consider developing a more detailed or specific set of behavioural expectations such as a fundamental expectations document for operations personnel. Regularly discuss the proper application of these principles as the plant progresses from construction through commissioning and on to operation.
- Ensure plant design changes that affect procedures and associated training lesson plans are communicated, evaluated and implemented as soon as possible.

Training and Qualification

- The scope of training should include technical, administrative and practical training for each of the core operating functions. The training function should also plan to provide quality leadership training for all supervisors and above on the leadership team.
- Establish executive alignment on the importance of training, which is communicated and reinforced throughout the organisation. Ensure that training attendance is an organisational priority supported by the leadership team.
- Establish a strong working partnership between the line organisation and their respective training group. Line ownership of training is an essential component of any healthy training program.
- For the core operating functions, develop a structured continuing training program. Implement this program for employees who have completed initial training and qualification activities.
- Plan to complete the development of your training programs, including all training materials, long before the scheduled start of training. Just-in-time development of your initial and continuing training programs and materials will likely result in lower quality training materials.
- Design training schedules to support completion of initial training prior to the start of commissioning activities (e.g. operations MCR personnel).
- Durations, methods and training sequences may need to be altered to facilitate effective learning. Training models that work in one organisation or culture do not necessarily work in another.
- Expect that some line personnel will not be successful in completing their technical training program. Each failure requiring remediation takes valuable resources away from the rest of the class, so have a plan to deal with failures (extra training staff, remediation plans, removal from program strategy, etc.).

- Quality training records are key to demonstrating staff qualification. Automate training records as much as possible (biometrics to record attendance, automated exam scoring/recording, etc.).
- Ensure vendors that are providing contracted support in core functions clearly understand and meet the training and qualification requirements for their staff, including participation in continuing training. An equivalency process to give credit for previously completed training can help minimize redundant training.
- If dealing with a workforce where English is largely a second language, yet it is the official language of the business, anticipate and put a strategy in place to deal with those who will struggle to be successful in training/qualification completion.
- Enact independent assessments to determine training effectiveness and readiness for operations crew performance observations and pre-startup review activities.
- If you are reliant on a vendor to provide training, ensure their program(s) and materials are thoroughly reviewed to confirm they will meet your organisation's unique needs and regulatory requirements prior to implementation. Repeat this verification exercise periodically to ensure sustained quality of training.
- Define standards of academic integrity. Put robust barriers in place for monitoring and verifying candidate integrity during test taking.
- Develop a First Line Supervisor (FLS) training program focused on instilling a nuclear safety culture that is supported by effective human performance (HU) standards.

Facilities and Equipment

- Invest in mock-ups and equipment/tools to facilitate initial and continuing training. Do this from the beginning. Such tools and mock-ups should help facilitate hands-on, practical training for trainees.
- Anticipate MCR simulator availability problems. Invest in additional simulator(s) to facilitate training and other plant activities. These can be useful in conducting Management SRO License Equivalency training of engineers, procedure validation, etc. Use limited scope, and partial task simulators as a cost-effective simulation tool.
- Anticipate larger than normal class sizes during initial training. Size your classrooms accordingly. Maintain a few extra classrooms as a contingency measure should you need to run simultaneous initial or remedial training courses.
- Ensure plant design changes that affect the simulator are communicated, evaluated and implemented as soon as possible.

Other

- Establish a relationship with the regulator to clearly understand regulatory requirements and expectations associated with training and qualification of station staff.
- Develop and implement standards of oversight when relying on vendor training to give plant-specific training and qualification credit.[26]

[26] WANO GL2005-01 guidelines for the Conduct of Training and Qualification Activities WANO GL 2008-02 Guidelines for Simulator Training

Key Expectations for Nuclear Professionals in the Training Classroom

1. Be on time for class. Return from breaks at the time specified.
2. Stay focused during class and avoid distraction (e.g. turn off phones and non-training electronic devices).
3. Be respectful of the instructor; do not distract others during class.
4. Ask questions. Answer questions when asked.
5. Be respectful of your classmates' questions, answers and opinions.
6. Study after hours to improve personal performance.
7. Help classmates learn before, during and after class where possible and appropriate.
8. Use independent effort during examinations. Do not undermine the development of other personnel by providing inappropriate assistance during examinations.
9. Provide open and constructive feedback on the quality of training when requested.
10. Participate in oral boards and other trainee-related activities outside of the classroom.
11. Avoid absences, including the use of personal leave, during scheduled training.

Figure E.2 Trainee Expectations Source: New Unit Assistance Working Group

Guidance for the Work Management (WM) Function

Before we begin, there exists varying opinions about WM throughout the nuclear industry – especially with respect to online work management (i.e. the scheduling, planning, preparation and coordination of work and testing activities performed while the plant is in operation.).

This document assumes that you will have defined a work management function that supports both outage and online maintenance. We do so because:

- It is conservative from a work scope and staffing perspective.
- Where regulation allows, online maintenance is considered helpful in maintaining plant equipment performance margins. It thus sustains a strong plant safety profile throughout the operating cycle.
- It reduces the scope of outage maintenance and testing activities. This creates an opportunity for enhanced outage performance – a major factor in overall plant performance.
- It exercises organisational discipline to the schedule … and thus improves organisational coordination and interaction (i.e. teamwork).

Staffing

- Prioritize WM hiring to allow for the development and implementation of WM processes, programs, procedures, work packages and the scheduling software prior to the turnover to the first system from commissioning to operations. This is intended to ensure the proper care and custody of plant systems and components while under the control of the operator. This includes efforts to implement preservation activities if required by the plant project schedule or incurred due to project delays.
- Hire a high percentage of previously licensed personnel (ideally on your chosen plant technology, although not required). These personnel are essential in establishing a high-quality (and thus credible) plant schedule.
- When hiring inexperienced, local personnel for entry-level positions where rapid learning and development is expected, evaluate:
    - Technical competency
    - Organisational skills
    - Motivation
- Work planners perform the essential task of building work packages for execution by qualified maintenance personnel. Work planners should be hired with significant plant experience. Initially, the work planning function should be located within WM, and not maintenance. The intent of this is to promote the adherence by these technically experienced and qualified personnel to program, process and procedure standards of performance. Doing so helps create work instructions of a common standard and quality for the end user, the maintenance worker. If desired, a transition of work planners to the maintenance function can occur after the first refuel outage.

Policy, Processes and Programs

- Define a WM transition plan to be followed as the plant progresses from FL to full power commercial operation.
- Scheduling and Planning
- Identify and schedule all planned turnovers of plant systems and areas from construction to operations. Do similarly for the completion and acceptance of all planned system testing.
- Develop a Level 1/Level 2 Outage schedule template, and ensure this template is aligned with the outage defence in depth model.
- Work with engineering and maintenance functions to develop a preventive maintenance scope of work for all plant equipment. Schedule and plan for this work early.

Schedule Execution

- Transition all work management processes to operations no later than system turnover to operations. This scope should include defect identification and screening, work package planning, scheduling, tagging, RP support, and all procurement support processes. This effort will help drive a transition to operating plant behaviours and standards, including establishing schedule discipline.
- Curtail non-critical work during the PAT period to minimize distractions and allow the MCR to focus on the execution of PAT.
- Plan to use plant operating test procedures for initial pre-startup operating surveillance testing. Do not take credit for commissioning test results.
- For both online and outage time frames, consider deploying a deliberate strategy of separating the maintenance and testing activities on redundant system trains of equipment by time (e.g. designate one week for maintenance on system train A and the next week for system train B, thus reducing the possibility of wrong train errors).

Procedures

- Create a “Conduct of Work Management” document defining the majority of operations protocols, standards and expectations. Do this referencing recognized industry bench marks for work management excellence identified by WANO. Consider developing a more detailed or specific set of behavioural expectations such as a fundamental expectations document for operations personnel. Regularly discuss the proper application of these principles as the plant progresses from construction through commissioning and on to operation.
- Carefully review and incorporate the quality guidance contained in INPO AP-928 Work Management. Build your WM process, program and implementing procedure guidance based on this guidance with allowance for local circumstance. Borrow from the industry, do not start from a blank page.
- Applicable WANO SOER recommendations should be considered during the development of WM and outage procedures.
- Define clear divisions of responsibility for the WM and outage processes.

- Define process flow maps. Use the swim lane concept to help define and depict clear authorities, responsibilities and points of interface between work groups. Verify that all outgoing transactions (designated by outgoing process arrows from the sender functions) have a receiver designated in the support department's procedures. Likewise, verify that all incoming transactions (designated by incoming process arrows from external functions) are recognized and captured in WM process and program documentation.

- Engage support organisations when developing the WM process. Identify and gain support for all process handoffs across functions. Verify the process flow maps are accurately captured in governing documents.

- Define contingency actions and manual methods for all WM activities in the event of business disruption events.

- Consider use of the EPRI risk modelling programs to allow for real time review of online and outage risk as a result of scheduled and emergent work activities.

- Develop and design the reports required to implement and monitor WM and outage processes. Develop key performance indicators (KPIs) based upon accepted WANO and INPO indicators.

- Bench mark (or purchase) procedures from a similar unit, and utilize content to the extent possible.

Enabling Business Enterprise Software

- Choose enterprise and scheduling software with a long and strong history of industry use in support of operational excellence. Such software has incorporated accommodations for industry best practice. Do not use EPC vendor-supplied software or home-grown software. There are additional costs, delays and frustrations in doing so.

- Adopt and implement a business enterprise software selection (e.g. SAP, Maximo, etc.) early in the project life.

- Adopt and implement scheduling software early in the project. Ideally this scheduling software would be used throughout the construction effort. Adopting the correct scheduling software early allows for the efficient integration, coordination and execution of all schedule activities in support of achieving project milestones. This will also allow for the efficient development of personnel scheduling competencies, and supports the later transition of construction personnel to operations.

- Verify that the specifications for plant data collection and receipt are conducive to the following:

    - Population of supporting WM, ER and CC databases and supporting software.

    - Transfer of plant equipment and work activity data between the business enterprise software and the scheduling software.

    - Development of reports and KPIs required to run and report on the WM and outage functions.

Training and Qualification

- Develop a matrix of training required and expected for each position within WM. Plan and budget to address the missing training needs.

- Aggressively enrol all WM staff in your plant operation familiarization training (see Section D). Build their operational knowledge of your plant to improve scheduling and planning competencies.
- Define a comprehensive list of required reading for WM personnel. Include INPO AP-928 Work Management and all WM process and program documents in this program.
- Develop positional job functional guides (JFGs) for all positions in WM and outage. Do the same for ancillary support positions (e.g. outage control centre (OCC) staff positions).
- To improve future outage performance, define the need, and then procure large scale mock-ups (e.g. steam generator channel head, reactor pressure vessel head, refuel equipment, etc.) in support of training of employee and contractor personnel.
- Use computer-based, e-learning modules to support the implementation of the WM process with key support personnel across all functions.
- Evaluate WANO, INPO and EPRI training and support opportunities for participation by your personnel.

Facilities and Equipment

- Determine a location for an operational control centre (OCC). Budget for it accordingly.
- Define early the required accommodations within the protected area for outage employees and contractors. Include allowances for facilities, catering, offices, IT and communication infrastructure, etc.
- Inter-connect the OCC and other outage support facilities with a robust communication and IT infrastructure.

Creating Organisational Teamwork

- Perform WM teambuilding events early to achieve internal alignment to WM processes, programs, protocols, standards and behavioural expectations. As applicable, use this to help remove any cultural barriers. Ensure internal alignment exists before attempting to achieve organisational alignment to WM processes, programs and protocols.
- Meet with the Project Management Organisation (PMO) and carefully review roles and responsibilities. Plan for the evolution of these roles and responsibilities as the plant progresses through commissioning, startup and operation. Create a transition document to clearly define and establish control points where the shift from commissioning processes to operating processes occurs.
- With the PMO, carefully define and plan for three key schedule transitions:
    - Transition the plant schedule from a construction activity heavy schedule to a commissioning heavy schedule.
    - Transition the plant schedule from a commissioning heavy activity schedule to an operations heavy schedule.
    - As necessary, integrate a large scope of operational readiness activities into the plant schedule.

- Develop a WM familiarization and training module to share with other functions. Take WM SMEs to each department and educate them on the work management process. Incorporate WM processes in other department training scope as appropriate (i.e. maintenance, operations, chemistry, engineering, etc.).
- Perform weekly meetings with the WM staff to routinely review goals, expectations, station top priorities, safety culture traits, and INPO/WANO standards.
- Refer to guidance for Outage Preparation provided in roadmap Section G

Section F: Engaging Industry Support

Introduction

There are a number of important relationships to be formed and nurtured over the next century of your plant and organisation's performance. Apart from the relationship with your regulator, none will likely be more critical than that formed with World Association of Nuclear Operators (WANO) and the International Atomic Energy Agency (IAEA).

These organisations exist to serve nuclear countries, nuclear regulators, and member nuclear utilities and plants. They are not-for-profit organisations. Generally speaking, IAEA support can be had for no cost and WANO support engaged at low cost. While other beneficial organisational relationships will be highlighted in this section of the roadmap, the primary intent of this section is to introduce you to the essential support and significant benefit of engagement with these two organisations.

> *"WANO and the IAEA have important roles to play in helping to bring about, on a global basis, the consistent good functioning of nuclear power that will help to improve public acceptance of the nuclear contribution to a global sustainable energy policy."*
>
> *Doctor Hans Blix, Director General of the IAEA, May 12, 1997*

So, what industry support is the most important to me and why?

International Atomic Energy Agency (IAEA)

The first of these critical relationships will be with the IAEA. The IAEA is based in Vienna, Austria. The supporting website can be found at https://www.iaea.org. Widely known as the world's "Atoms for Peace and Development" organisation within the United Nations family, the IAEA is the international centre for cooperation in the nuclear field. The agency works with its member states and multiple partners worldwide to promote the safe, secure and peaceful use of nuclear technologies.

A new nuclear project is typically an extension of a country's existing nuclear, political, commercial and regulatory structure. In these cases, the existing IAEA point of contact reaches out to the new build effort as an expansion of an existing national relationship. A new IAEA point of contact will be assigned, and a subsequent relationship formed, for new build efforts in new nuclear countries.

The IAEA can provide you a broad range of useful guidance. This guidance is captured within documents referred to collectively as IAEA safety standards and publications. These documents address the full scope of project phases from initial program feasibility studies through plant operations. The IAEA's areas of significant expertise include plant design, construction, licensing, environmental and security.

World Association of Nuclear Operators (WANO)

WANO was formed in May 1989 as the nuclear industry's collective response to the Chernobyl accident. WANO was formed, in part, based on the operating model established by the Institute of Nuclear Power Operations (INPO). This U.S.-based organisation was formed after the earlier accident at Three Mile Island in 1979.

WANO is the global leader in the nuclear safety of operating nuclear power facilities. WANO has built operational expertise in part through the analysis and corrective actions tied to industry events, most recently, the 2011 accident at Fukushima. WANO's mission, and thus focus, is to maximise the safety and reliability of nuclear power plants and fuel reprocessing facilities worldwide.

While membership is voluntary, all operating nuclear plants worldwide are expected to become WANO members. WANO membership is defined in five categories, the first two of which will apply to you. Category 1 includes nuclear utilities as the owners and operators of nuclear power plants. Category 2 membership includes nuclear plants like yourself.

The WANO organisation is led from a central office in London, England. The WANO public website is https://www.wano.info and the supporting member website can be found at https://members.wano.org/.

There are four WANO regional centres. The centres are listed here in alphabetical order:

1. WANO Atlanta Centre https://www.wano.info/centres/atlanta-centre
2. WANO Moscow Centre https://www.wano.info/centres/moscow-centre
3. WANO Paris Centre https://www.wano.info/centres/paris-centre
4. WANO Tokyo Centre https://www.wano.info/centres/tokyo-centre

In January 2020, a branch office will be established in China as a first step in the process of establishing a fifth WANO regional centre, the WANO Shanghai Centre.

A nuclear entity's alignment to a regional centre is typically based on a combination of geography and new plant technology. Per WANO Member Policy PD-5, affiliation with your WANO regional centre formally begins with the first placement of nuclear grade concrete (FCD). Earlier engagement via the central WANO London Office is possible. You are strongly encouraged to take advantage of this opportunity and establish an organisational agreement for early engagement.

Early engagement with WANO is hugely beneficial to the new member. Early stage nuclear program development will benefit from the operational expertise of WANO's personnel via specific new unit assistance missions as well as access to WANO guidance documents, operating experience data, and a variety of other support services. Your WANO relationship will form, grow and strengthen as you approach nuclear plant operation – WANO's area of significant expertise and focus.

WANO is funded by member utilities. Again, it is a non-profit. New entrant engagement will cost approximately £30,000 annually. This sum represents about half the typical annual membership dues to be expected from a two-unit facility.

What information and supporting guidance can I expect from WANO and the IAEA?

Both WANO and the IAEA are rich with guidance to assist in your preparation for plant operation. A master list of this broad array of guidance can be found in Appendix 6. More broad and exhaustive listings of valuable resources and guidance can be found on their respective member websites. You are encouraged to search these valuable sources for information early in your journey.

IAEA Safety Standards and Publications:

The industry guidance provided by the IAEA is captured within documents referred to collectively as IAEA safety standards and publications. This rich and diverse collection of reference material is publicly available. The IAEA Safety Standards can be found at https://www.iaea.org/resources/safety-standards. A far more user-friendly bibliography of IAEA publications relevant to your task can be found at the following: https://www.iaea.org/topics/infrastructure-development/bibliography#1. The content cited at this location is tailored to the new nuclear entrant and operator. It is a great place to begin your exploration and research.

The document hierarchy of IAEA safety standards and publications is very well structured. The focus of the guidance provided by the IAEA is the earlier phases of the new unit experience. Much of that focus pertains to the nineteen areas of program infrastructure introduced earlier in section D of the roadmap.

WANO Guidance:

Again, per WANO member policy, full access to all WANO guidance documents occurs formally once you are affiliated with a regional centre. With an organisational agreement in place, earlier access to WANO guidance is made possible via your designated London office point of contact.

WANO documents are broken into two main categories, governance documents and technical documents. Governance documents explain the inner working of the WANO organisation. These governance documents include a charter, articles of association, policy documents, programme guides, and implementing procedures and manuals.

More immediately important to your operation is access to the vast array of technical documents. Technical documents include operational principles and guidelines, significant operating experience reports (SOERs), the citing of good practices, and the performance objectives and criteria (PO&C) document. In addition, WANO will provide you access to its operating experience database containing reports from its members.

Your WANO point of contact will familiarize you with the type and location of helpful guidance materials.

Early on, we emphasized the importance of starting with the end in mind. As you define and build your operating model and prepare your organisation for full power operation, it is helpful to understand how your organisation will eventually be assessed once normal operation begins. As one would expect, you will be assessed based on plant operating performance results, organisational effectiveness, and the underlying integrity and strength of your operating model. The basis of these assessments is tied to the following three critical WANO documents:

1. WANO Performance Index (WANO Performance Indicator Process Description PCD 2014-02)

   This document defines the eight critical plant performance metrics that are incorporated into a composite index of overall plant performance. The document provides exact guidance on how you will ultimately collect data and calculate these associated metrics. Your plant's performance will be reported to WANO monthly. Your plant's data and that of your industry colleagues will be collected, complied and presented in aggregate once a quarter. This compilation of metric data will provide you significant insight into your plant's performance in eight key areas when compared to your industry colleagues. The business planning component of your operating model should include the annual comparison and detailed gap analysis of your performance compared to top quartile (or decile as desired) performance in a given area. Subsequent business plan actions should strive to close these gaps in pursuit of improved safety margins and plant performance gains.

2. WANO Performance Objectives & Criteria (PO&C 2019-01)

   This document describes the expectation for the fundamentals of safe nuclear plant operation. It defines the full scope of objectives and criteria to be used when assessing plant and personnel performance. Understanding this document will help you build a stronger operating model and help guide your efforts towards optimizing organisational effectiveness. The PO&Cs will help you define the standards to be incorporated into all processes, programs and supporting procedures, as well as the proper professional behaviours to be embraced and exhibited by your personnel.

Note: As a new nuclear unit, you will first be expected to meet an abbreviated version of PO&Cs defined for the startup of new nuclear plants and organisations. These may be found in WANO reference Pre-Startup Peer Review (PSUR) Performance Objectives and Criteria (PO&C 2013-2)

3. Significant Operating Experience Reports (SOER)

   WANO SOERs are the reported outcome of industry event analysis. An SOER highlights operational concerns requiring a higher level of focus and attention by its members. These reports usually address a concern derived from multiple industry events, but can also be based on a singular event. The intent of these reports is to inform members of significant safety issues that have potential applicability to many or all industry plants.

   SOERs examine a significant industry event or trend of similar events of significance. They provide in-depth analysis and identify the underlying causes of events to include organisational weaknesses that resulted in failed safety barriers. The purpose of SOERs is to help identify important safety issues and to provide information to aid WANO members in identifying their vulnerability to similar events.

   SOERs provide WANO member utilities and stations the opportunity to take proactive steps to eliminate operating risks and improve plant performance without experiencing the initial impact, cost, potential public embarrassment, and emotional stress of similar events. SOER reports highlight lessons learned and, most importantly, recommend actions as a basis for member self-assessment. Where applicable, improvement actions to strengthen an organisation's operating model, improve safety margins, and reinforce nuclear professional behaviours. These efforts can prevent similar events at your plant.

   For example, "SOER 2013-02 Post Fukushima Daiichi Nuclear Accident Lessons Learned" provides members valuable insights for addressing design vulnerabilities and strengthening emergency response capabilities.

   As depicted in the figure below, there are 17 SOER reports that make 236 total recommendations. WANO members commit to two things. First, taking action to formally review and assess all SOER recommendations for applicability. Second, taking action to implement those recommendations deemed applicable. Applicable SOER actions can be built directly into your organisation's operating model early and serve to strengthen the scope and quality or processes, programs, procedures, facilities, equipment, training, contingency actions, etc.

Table F.1 Significant Operating Event Report (SOER)

#	SOER	SOER Title	# of Recommendations
1	1998-1	Safety System Status Control	6
2	1999-1	Loss of Grid	21
3	2001-1	Unplanned Radiation Exposure	13
4	2002-1	Severe Weather	6
5	2002-2	Emergency Power Reliablity	9
6	2003-2	Reactor Pressure Vessel Head Degradation (Davis Besse)	10
7	2004-1	Managing Core Design Changes	5
8	2007-1	Reactivity Management	26
9	2007-2	Intake Cooling Water Blockage	13
10	2008-1	Rigging, Lifting and Material Handling	20
11	2010-1	Shutdown Safety	22
12	2011-1	Large Power Transformer Reliability	20
13	2011-3	Nuclear Spent Fuel Degradation; Loss of Cooling & Makeup (Fukushima Daiichi)	7
14	2013-1	Operator Fundamentals Weaknesses	12
15	2013-2	Post Fukushima Daiichi Nuclear Accident Lessons Learned	33
16	2015-1	Safety Challenges from Open Phase Events	6
17	2015-2	Risk Management Challenges	7
		Total	236

Source: New Unit Assistance Working Group

Be aware that an additional source addressing slightly less significant events and trends exists. This vehicle, Significant Event Reports (SER) issued by WANO, is available in support of industry learning and improvement efforts.

One additional guidance document of critical importance should be incorporated into your model of operation. This document, WANO Performance Analysis Programme Guide (WPG-02), describes the standard definitions and criteria for the various types and levels of potential plant events. The guidance will serve as the basis for plant event reporting and, in doing so, help demonstrate organisational transparency. It will also help determine the effectiveness of your organisation's event prevention and error minimization program efforts. Thus, the guidance will help you accurately and credibly characterize your site's performance when compared to your industry colleagues.

The entirety of the plant performance measures, operating standards, and SOER recommendations discussed above serve as a rich source of information to be carefully examined and considered when building your operating model.

What hands-on assistance and assessment can I expect from WANO and the IAEA?

During your organisation's multi-year journey toward operational readiness, both WANO and the IAEA can provide assistance and will conduct critical assessments. The assistance and assessments described in the coming pages will require organisational time, energy and focus.

Prescribed assessments are mandatory for any member in good standing. Taking advantage of assistance, while voluntary, is STRONGLY RECOMMENDED.

Your WANO representative is an important partner in your journey. They are there to facilitate any and all types of assistance as required. The WANO representative may be site based (e.g. Moscow centre) or, as is more typical, visit your site quarterly. During site visits, your representative can be expected to review plans and documentation, conduct field observations, and conduct interviews with a variety of personnel throughout the organisation. They will openly share observations made, insights gained, and discuss further assistance you may require. A strong, open and respectful relationship with your WANO representative is important to your success.

Shortly after your acceptance as a WANO member, your WANO representative, in coordination with IAEA personnel, will convene with you to draft a comprehensive plan for WANO and IAEA assistance and assessment. This plan will focus on scope and schedule. It will also carefully consider your specific and unique circumstances and the need for any special support efforts.

What specific assistance can I expect?

Before we begin, note that both WANO and the IAEA will take a graded approach to the support of new units. Accordingly, new nuclear construction projects in established nuclear countries and/or companies may require less support than those with less mature infrastructure. Appropriately, more significant levels of support and assistance will be provided for a new nuclear project, in a new nuclear company, in a new nuclear country, where the regulatory framework is being developed in parallel with the new build.

IAEA Assistance:

In addition to the written guidance indicated in the previous section, the IAEA provides a wide range of educational resources for new members. These educational resources include online training courses. Further, an annual slate of seminars, conferences and classroom training sessions are communicated on the IEAE website and available to new nuclear entrants.

Upon request of your IAEA point of contact, additional effort to visit your project and provide more bespoke assistance can be arranged.

WANO assistance:

Early in your development cycle, WANO will offer to conduct a number of targeted member support missions (MSM). Each of these support missions will utilize a pre-existing guideline referred to as a New Unit Assistance Module. The modules are designed to help new members develop important functional capability in preparation for operation. WANO reference document PCD 2015-01 and supporting NUA brochures outline this program of support.

These missions are typically conducted by a collection of WANO staff (often augmented by experienced, sister plant personnel) with expertise in the targeted functional area. These experts will visit your corporate office and/or site and meet with your team of equivalent functional personnel. This assistance will help define relevant policies and standards and assist in creating associated programs, process and procedural requirements and content. Additionally, they will provide select guidance and support on implementation.

For a given functional capability, WANO will:

- Introduce industry personnel with expertise to include WANO and sister plant personnel.
- Highlight important reference publications available from WANO and the IAEA.

- Share lessons learned from previous industry events, to include <u>required</u> program and process elements and standards.
- Suggest best practices created and employed by sister plants and organisations. Best practices are determined based on both the strength of foundational governance and performance.*
- Introduce other available industry resources and opportunities.
- In some cases, provide examples of specific materials.

*Note: WANO will typically facilitate introductions and visits with targeted sister plants as desired.

As of December 2019, the available list of 18 recommended New Unit Assistance (NUA) Modules are:

1 Safety Culture
2 Operator Fundamentals, Crew Performance and Teamwork
3 Organizational Effectiveness (OR), Oversight and Leadership Effectiveness
4 Operational Decision Making
5 Training
6 Significant Operating Event Reports (SOER)
7 Emergency Planning and Management
8 Operating Experience (OE) Programme
9 Performance Improvement Processes
10 Fire Protection and Management
11 Maintenance
12 Engineering
13 Fuel and Reactor Management
14 Equipment Performance and Condition
15 Chemistry
16 Turnover for Operation
17 Radiation Protection
18 Work Management

Three additional modules – Corporate, Internal Communications, and Refuelling Outage are being contemplated for development and deployment in 2020.

The schedule for the conduct of these modules will be laid out consistent with the typical cycle of operational development discussed earlier in Section D. The timing and schedule of your modules will look something like that depicted as follows:

Figure F.1 Typical WANO Assistance Timing

Construction Period				Hot Functional Testing	Startup & Testing	First Cycle of Operation	Refuel Outage
48 Months				18 Months	6 mo	12 Mo	3 Mo
Year 1	Year 2	Year 3	Year 4	Year 5			
		Corporate (2020)					
Training	Chemistry	Safety Culture	Operator Fundamentals / Crew Performance	Operational Decision Making			
Significant Operating Event Reports (SOER)	Turnover for Operation	*Internal Communications (2020)*	Engineering	Maintenance			
Operating Experience (OE)	Emergency Planning	Organizational & Leadership Effectiveness	Work Management	*Refuelling Outage (2020)*			
Fire Protection	Performance Improvement Processes	Equipment Performance and Condition	Fuel & Reactor Management	Radiation Protection			

Source: New Unit Assistance Working Group

Additional support from WANO to meet your specific organisational needs can be designed and provided upon request.

Depending on member need and circumstance, an MSM may take different forms, to include some or all of the following: visits, remote material reviews, on-site training and seminars, workshops, benchmarking material and/or trips to sister plants. Members should work to schedule these visits early in the development cycle for each particular area of applicability. Your WANO representative will collaborate with you to determine the scope and timing of those missions that are most appropriate for your organisational and plant-specific circumstances.

A note of caution: Before conducting any one of the above NUA assistance modules, the member should ensure sufficient leadership and expertise exists in the targeted functional area to support a meaningful and constructive experience.

There exists one additional MSM, the Operational Readiness Assistance (ORA). The intent of the ORA is to assist a member evaluate its level of readiness for formal plant assessments. This should help inform the extent of additional preparation activities required and the timing of formal assessments to be conducted by WANO and the IAEA. The ORA should occur approximately 15 months prior to your planned fuel load date and 12 months prior to your plant pre-startup review assessment (to be discussed in the following section). The typical scope of this assistance includes the areas of organisation and administration (OR), operations (OP), maintenance (MA), including foreign material exclusion (FME), equipment performance and condition (EQ), and fire protection (FP), as well as a review progress on the assessment and action tied to SOER recommendations. Additionally, most recent industry experience suggests a careful review of corporate structure and the effectiveness of its functional support of operations is warranted.

Depending on the need and circumstances, the scope of an ORA can be very comprehensive or more targeted. The WANO representative is a key partner in determining the recommended scope of the ORA. The scope will be based upon “WANO Reference: Pre-Startup Peer Review (PSUR) Performance Objectives and Criteria (PO&C 2013-2).”

Upon completion of any MSM, the member will receive a formal report from their WANO regional centre representative containing recommendations and suggestions. The member is expected to enter this input into the corrective action program and develop corrective actions and a formal improvement plan. This plan will be shared and updated with your WANO representative during subsequent visits within the ensuing six months.[27]

What specific <u>assessments</u> can I expect?

For the operators of a new plant project, there are two critical operational assessments that you must be concerned with, namely, the IAEA’s Pre-OSART assessment and WANO’s Pre-Startup Review (PSUR). We will discuss both in detail shortly.

For new nuclear entrant countries with a new nuclear program, there are seven other IAEA assessments under the IAEA framework of which to be aware. These seven IAEA assessments (listed below) focus on the 19 national infrastructure elements critical to a new nuclear program. These assessments begin in phase one of a new nuclear program and complete at the end of phase four prior to plant commercial operation.

1. Integrated Nuclear Infrastructure Review (INIR)
2. Site and External Events Design Review Service (SEEDS)

[27] MN | 2016-1 Conduct of Operational Readiness Assistance (ORA) Missions

3. Integrated Regulatory Review Service (IRRS)
4. Emergency Preparedness Review Service (EPREV)
5. International Nuclear Security Advisory Service (INSServ)
6. International Physical Protection Advisory Service (IPPAS)
7. IAEA Safeguards Advisory Service Mission (ISSAS)

The first assessment cited above, the INIR, occurs in three parts. Each part closes out a particular program phase. All of the above assessments apply to national infrastructure and are thus important to the operator. For a new nuclear operator, some of the above assessments can have impact on your specific project. A careful review of findings and insights from the above can result in needed upgrades to your operating model and associated functions and/or programs. These include emergency preparedness, security and safeguards. Specifically, INIR Missions for Phase 3 evaluates the status of the infrastructure development against the readiness for commissioning and operating the first nuclear power plant in the host country. INIR missions for Phase 3 provides an overall integrated view of infrastructure to help host country start commissioning and operation in a well-managed and coordinated manner.

Let us move on to the more relevant operational assessments.

Critical Operational Assessments:

The IAEA and WANO will each provide a critical assessment of plant and organisational readiness for safe plant operation. The first assessment, the IAEA Pre-OSART assessment, is voluntary. It occurs only when a country's government organisation or nuclear regulatory body requests the IAEA to do so. The second, the WANO PSUR is mandatory. The results of the IAEA and WANO assessments must be satisfactory for the operator to move forward with fuel load and eventual operation. Critically, the PSUR can yield Startup-Related Areas for Improvement (SRAFI) - to be discussed later – that must be satisfactorily resolved prior to fuel load or first criticality at the latest.

Be advised, that your regulator should be, and hopefully is, very interested in the outcome of your formal assessments. They may well use the outcome of the assessments and the quality and thoroughness of your corrective actions as criteria in either granting an operating licence or granting their permission to load fuel and startup.

IAEA Pre-Operational Safety Review Team (Pre-OSART) Review:

One of the IAEA's safety review services is the Operational Safety Review Team (OSART) programme. Established in 1982, the OSART programme has provided advice and assistance to member states for more than 30 years, in order to enhance the safety of nuclear power plants during construction, commissioning and operation. The bases of the review are the IAEA safety standards, many of which are adopted within the nuclear regulatory framework of the member states of the IAEA.

OSART reviews have taken place in all countries operating nuclear power plants. Each OSART mission is conducted by a team of experts drawn from all regions of the world. An OSART review takes place during the latter stages of a nuclear power project's commissioning phase. This assessment is referred to as a pre-operational OSART, or pre-OSART.

The agency preference is to conduct a Pre-OSART about three months prior to the initial loading of nuclear fuel and one month prior to the WANO PSUR (to be discussed shortly). An OSART mission is requested by a nuclear power plant or utility via its national nuclear safety regulatory authority or other relevant governmental body. A request for an OSART mission should be transmitted to the

IAEA deputy director general, nuclear safety and security department, 18-24 months prior to its targeted need date. The Pre-OSART assessment should be scheduled at least six to nine months prior to the conduct of the planned assessment. This time frame allows the IAEA time to effectively plan and coordinate industry assessment resources. Scheduling of the Pre-OSART should be done in close collaboration with your IAEA representative.

Upon completion of the Pre-OSART review, the team leader (TL) will prepare the Pre-OSART report. This is an official IAEA document, which summarizes the team's main observations and conclusions. This report is provided electronically through official channels to the member state which requested the Pre-OSART. The TL also sends electronic copies to both plant management and the regulator.

The IAEA restricts initial report distribution to in-house users, the utility, and the regulatory authority. Unless the member state indicates otherwise, the report is automatically derestricted after 90 days and the main conclusion is published on the IAEA OSART website. Most member states post the full, derestricted report on their official public website to demonstrate transparency and grow public trust.

WANO Peer Team Pre-Startup Review (PSUR):

The PSUR is an assessment of operational readiness for safe plant startup and subsequent operation. The assessment is conducted in accordance with WANO reference document, PO&C 2013 -2. The PSUR includes a very important assessment of MCR operating crew performance (i.e. the Simulator Operations Crew Performance Observation). The preferred timing of a PSUR is after the completion of hot functional testing, but before the initial loading of nuclear fuel to the reactor. The PSUR should be scheduled at least six to nine months prior to the planned assessment. It should be conducted approximately two months prior to a high confidence planned fuel load date. The former time frame allows WANO the time to effectively plan and coordinate industry assessment resources; the latter allows for adequate member organisational response to the assessment prior to fuel load. Scheduling of the PSUR and CPO should be done in close collaboration with your WANO representative.

Note that the scope and structure of the PSUR may be adjusted in coordination with your WANO regional centre and representative based on the scope and outcome of the Pre-OSART assessment.

In addition to the assessment scope outlined in WANO PSUR PO&C (2013-02), the PSUR will include a rigorous assessment of the 236 recommendations embodied within the 17 SOERs. For plants with multiple units, the assessment of the full scope of SOER recommendations will be distributed across the multiple PSURs to be conducted for the entirety of the units.[28]

Startup-Related Areas for Improvement (SRAFI):

The WANO CPO and PSUR reviews can yield Startup-Related Areas for Improvement (SRAFI). Corrective actions for SRAFIs must be well crafted and satisfactorily executed. The associated issue must be resolved to the satisfaction of WANO prior to fuel load (or potentially first criticality) and subsequent startup of the unit. Satisfying a WANO SRAFI most often requires a follow-up visit. During this follow-up visit, the WANO team will confirm that all planned improvement actions are

[28] PO&C 2013-2 WANO Pre-Startup Performance Objectives and Criteria

WPG06 WANO Pre-Startup Peer Reviews

PCD 2013-4 Pre-Startup Reviews Schedules

PCD 2013-6 Conduct of Pre-Startup Peer Review Crew Performance Observations

WANO PSUR How-to Guides

executed and that the actions have yielded the intended performance impact. Additional MSM support may be requested and executed in support of addressing and resolving a SRAFI. It is essential that you work closely with your WANO representative to define SRAFI corrective actions.

The recent decade of industry experience conducting WANO PSURs has yielded the following probability for the number of SRAFIs identified and written up for new units by the Pre-Startup Review Teams:

Number (#) of SRAFI Received during PSUR	% of PSUR's conducted with # SRAFI	% of PSUR's conducted with # SRAFI or Lower
0	5	5
1	20	25
2	65	90
>= 3	10	100

Table F.2: Startup Related AFI Performance

By way of illustration, operating experience suggests 25% of new units will receive one or fewer SRAFI during its PSUR. Only 5% of new units receive no SRAFIs; whereas, less than 10% of new units earn 3 or more SRAFIs.

Source: New Unit Assistance Working Group

The above summary data is shared with you, the member, as a basis for pre-planning and objective setting and for post-assessment of your performance as compared to your industry peers. While the above represents the industry's aggregate experience, your outcome is dependent on the quality of your development activities. Early preparation, use of industry and WANO assistance, and leveraging sister station lessons learned and best practices should improve your assessment results.

During this same period of assessments, the most commonly identified SRAFI areas include:

- Reactivity management
- Readiness of safety-related systems for startup
- Main control room operating crew performance and supervision
- Operating procedures
- Foreign material exclusion practices around nuclear fuel and associated support systems
- Fire protection

For more detailed information regarding weaknesses identified during PSUR assessments, see WANO Report 2019-05. "Analysis of Startup Related AFIs identified by WANO Pre-Startup Reviews from 2013 to 2018". Note: This document does not include company or plant unique identifiers. Like all WANO peer review assessments, the individual plant results of the PSUR assessment are strictly confidential.

When reviewing this document, concentrate on the underlying causes for each SRAFI. Focused and effective efforts to eliminate these causes in your plant or with your staff should prevent SRAFIs.

Following your PSUR, the WANO representative will work with your leadership team to help develop a corrective action plan to address program development and performance gaps identified during the PSUR.

In the circumstance where multiple units are being constructed and commissioned for operation, a PSUR is conducted for each subsequent unit. Subsequent PSURs conducted for the next sequential units will include a review of early operation of the previous unit(s).

What must I do to properly prepare for and execute an external assessment?

WANO and IAEA assessments are both large-scale evolutions requiring significant preparation, impactful execution, and rigorous (and potentially large-scale) follow-up actions. An assessment of your operational readiness is only as accurate as can be determined by a reasonable review of your pre-materials and the scope and depth of the assessment team's observations, interviews and reviews of relevant plant documentation.

The assessment team will typically include 15 to 20 persons. This team will be ready to commence assessment virtually upon arrival at your organisation and site. The conduct of the assessment on-site will take approximately two weeks (several days longer for a pre-OSART).

You, as the operator, desire a fair and accurate assessment. The assessment will be based on a review of all plant documents and reports and the extent of observations made and interviews conducted. This will serve as the basis to validate satisfactory achievement of each of the assessment's PO&Cs. Thorough preparation and strong review team support are the keys to receiving a quality assessment. The timing of recommended assessment preparation and execution activities is provided as follows:

Twelve months prior to the formal performance review and assessment (Approximately 15 to 18 months prior to FL):

- The assignment of a WANO/IAEA assessment team lead to oversee organisational preparations, assessment execution, and facilitate follow-up corrective actions.
- Facilitate the conduct of an organisational self-assessment. For the WANO PSUR, the output of the Operational Readiness Assistance (ORA) will satisfy this requirement if all areas have been assessed.
- Project the timing of the formal assessment. Coordinate the scheduled timings for the assessment with the assessing body.
- For the pre-OSART mission, conduct a preparatory meeting with the IAEA. During this session the IAEA will brief senior team leaders, the assessment team leader, and potential assessment team members on the process and methodology for the Pre-OSART mission.

Nine months prior to assessment:

- Identify your organisation's host peer, or that person who will interface with the assessment team and provide leadership for site preparations and assessment execution.
- Identify your organisation's assessment team counterparts. (Note: A counterpart is that person you designate from within your organisation to engage with the assessment team member of similar functional expertise.)
- Develop assessment indoctrination training for your assessment support team.

- Where possible, work with your WANO and IAEA representative to allow designated assessment support personnel (i.e. your host peer and counterparts) to participate in pre-OSART and WANO peer reviews at other facilities. Doing this will help familiarize your organisation with the assessment process, the level of scrutiny to be expected, and standards of performance your plant and organisation will be measured against.

Six months prior to assessment:

- Conduct assessment indoctrination training for your assessment support team.
- Prepare and submit to the assessing organisation an advance information package in accordance with the team's request. Fulfilment of this request will entail a large body of information. Plan for 60 days to understand, prepare, assemble and submit this formal body of documentation.
- Review the top SRAFIs from recent PSURs.
- Review status of SOER recommendation implementation.
- Facilitate formal management reviews of organisational readiness. Focus on recent industry PSUR SRAFIs.
- Confirm the schedule with the assessing body.

Caution: The WANO and IAEA assessments are logistically complex and require a significant coordination of both internal and external resources. Changes to the schedule are hugely impactful to the assessing organisation. Work hard to avoid schedule changes.

Three months prior to the assessment

- Conduct training with your organisation's host counterparts.
- Plan for and commence the conduct of assessment training with the organisation.
- Obtain assessment team member information. Begin planning logistics to include work visas and plant access.

One month prior:

- Conduct regular update meetings using all applicable checklists and follow-up actions - a minimum of twice weekly is recommended.

One week prior:

- Verify all assessment logistics.
- Conduct final organisational briefings. Share assessment "Dos and Don'ts".

Conduct the Assessment:

- Conduct formal entrance meeting.
- Conduct formal closure meeting. Verify that all facts recorded by the assessment team are valid. Receive briefing of preliminary findings.

Post-Assessment:

- Commence the development of formal action plans based on preliminary findings.
- Provide the organisation a preliminary briefing of results.*
- Receive and review the draft assessment report.
- Complete and submit a final assessment corrective action plan.
- For PSUR, schedule follow-on assessment of completed actions in response to identified SRAFIs.

30 Days Post-Assessment:

- Receive the final WANO assessment report. The final Pre-OSART mission report will arrive in approximately three months.
- Communicate your assessment results to the organisation.

  Note: The IAEA pre-OSART report can be made public by the host organization. The WANO PSUR report is company confidential. The member is encouraged to share openly, but carefully, the content and findings of both assessments with employees and regulators. While WANO PSUR results and insights should be shared and discussed with employees, the written report should not be circulated nor released.

- For PSUR, conduct formal follow-on assessment of any SRAFIs.
- Begin implementing the complete scope of assessment corrective actions.

Once identified WANO PSUR SRAFIs are satisfactorily addressed and assessed, commence fuel load, reactor startup and plant operation.

Six to nine months post-assessment:

- Conduct a formal effectiveness review of assessment corrective action plan

Given the suggested timings for the conduct of your assessments and the long recommended pre-planning scheme, preparations for the IAEA pre-OSART and WANO PSUR may overlap. If planned carefully, this overlap can be beneficial. With a careful review of the varying requirements for both assessments, the operator can optimize its preparations in several ways. By way of example, operator assessment team members can be the same and pre-submission paperwork can be similar. Additionally, the assessment logistics and protocols for the conduct of the first assessment, the pre-OSART, can be assessed and improved upon during preparation for the second, assessment, the PSUR.

The entirety of your pre-startup assessment preparation experience will not be wasted. The operating assessments conducted by WANO (Peer Reviews) and the IAEA (the OSART) will occur regularly throughout your operating lifetime. The preparation for these operating assessments will be just as demanding if not more so. It is recommended that you get ahead of this by capturing your experience and lessons learned in procedures and checklists to improve the effectiveness and efficiency of your preparations for the conduct of future assessments.

To close this section, a simple summary schedule for the conduct of these critical assessments is provided:

- Start Organisational Self-Assessment (3 months) — 18 months prior to Fuel Load
- Conduct Operational Readiness Assistance (ORA) — 15 months prior to Fuel Load

- *Conduct IAEA Pre-OSART 3 months prior to Fuel Load
- *Conduct WANO PSUR / CPO 2 months prior to Fuel Load

*Note: As an operator, you will find the currently preferred schedule timings for these two assessments very difficult to execute. The biggest challenge with the timing shown is the one month interval between the two assessments. One month affords the operator little to no time to adequately review and properly respond to the IAEA findings prior to the subsequent WANO PSUR assessment. To address this, WANO and the IAEA work closely together to coordinate these assessments to help optimize the workload on the operator. The NUAWG is working with WANO and the IAEA to help further enhance the efficiency of these important assessments. In the meantime, it is recommended that you meet jointly with your site representatives to establish an interval of three to six months between the conduct of the WANO and IAEA assessments.

Summary

WANO and IAEA assistance and assessments efforts are characterized in the two tables that follow. A summary of pre-operational assistance and assessment interactions and their characteristics can be found in table 1.

After fuel load, plant startup, and the commencement of operations, WANO and the IAEA will continue to provide both assistance and assessment. A summary of these post operational assistance and assessment interactions and their characteristics can be found in table 2.

A WANO Corporate Peer Review will occur approximately one year after initial criticality of the first unit. The review will cover PO&C 2013 Sections CO.1 through CO.7. For most plant technologies, the first Plant Operational Peer Review will occur sometime after the first complete cycle of operation.

Table F.3 Summary Table of Assistance and Assessment Characteristics Pre-Plant Startup and Operation				
Industry Interaction	Industry Group	Interaction Type	Outcome	Utility Response Required
Member Support Missions (MSM)	WANO	New Unit Assistance	Recommendations	Follow on action to create the functional capability targeted. Submit to WANO. *
			Suggestions	No action required
Operational Readiness Assistance (ORA)	WANO	Assistance (critical pre assessment preparation)	Recommendations	Create action plan for accelerated preparation for critical industry assessment. Submit to WANO.
			Suggestions	No action required
Pre-Operational Safety Review Team (Pre-OSART)	IAEA	External Assessment	Recommendations	Create action plan for improvement
			Suggestions	Create action plan for improvement
WANO PSUR (& CPO)	WANO	External Assessment	Startup Area for Improvement (SRAFI)	Create action plan for improvement. Correct issue satisfactorily and pass follow-up assessment prior to the specified startup milestone, typically fuel load, but never later than reactor startup and first criticality. Submit to WANO*.
			Area for Improvement (AFI)	Create action plan for improvement. Submit to WANO*.
			Identified Performance Strengths **	No action required

Source: New Unit Assistance Working Group

Notes:

*For all WANO assessments and MSM recommendations, conduct a formal effectiveness review, typically 6 to 12 months post implementation. WANO will conduct an independent effectiveness review of each of your corrective actions.

** Performance strengths identified during performance review assessments are often highlighted to other stations across the world struggling in that particular performance area. Requests for bench mark visits by other stations can be expected.

Source: New Unit Assistance Working Group

Table F.4 Summary Table of Assistance and Assessment Characteristics **Post**-Plant Startup and Operation				
Industry Interaction	Industry Group	Interaction Type	Outcome	Utility Response Required
Member Support Missions (MSM)	WANO	Assistance (as requested)	Recommendations	Create action plan for improvement. Submit to WANO*.
			Suggestions	No action required
Plant Peer Review	WANO	External Assessment	Areas For Improvement (AFI)	Create action plan for improvement. Submit to WANO*.
			Identified Performance Strengths **	No action required
Corporate Peer Review	WANO	External Assessment	Areas For Improvement (AFI)	Create action plan for improvement. Submit to WANO*.
			Identified Performance Strengths **	No action required
Operational Safety Review Team (OSART)	IAEA	External Assessment	Recommendations	Create action plan for improvement
			Suggestions	Create action plan for improvement

Source: New Unit Assistance Working Group

Notes:

*For all WANO assessments and MSM recommendations, conduct a formal effectiveness review, typically 6 to 12 months post-implementation. WANO will conduct an independent effectiveness review of each of your corrective actions.

** Performance strengths identified during performance review assessments are often highlighted to other stations across the world struggling in that particular performance area. Requests for bench mark visits by other stations can be expected.

Other Industry Support

What other industry support is available that can add real value to my program and project? (In alphabetical order)

Note that export controls limitations will not preclude membership and participation in the following organisations, but may limit the extent of technical material shared.

Electric Power Research Institute (EPRI) https://www.epri.com

EPRI provides a host of collaborative research services for the development of technologies that enable the safe, reliable, economical operations of existing nuclear power plants and the deployment of advanced nuclear power, as well as field guides, research reports, technical bulletins and downloadable software. EPRI has served the industry well by effectively helping member participants understand, analyse and resolve and/or prevent difficult technical problems.

The EPRI member centre is home to numerous research topics covered by EPRI, including non-destructive testing, material management, long-term operations, chemistry and radiation, fuel reliability, advanced nuclear technology, risk and safety, etc.

Access to EPRI content and services are available via paid memberships. Membership is a fixed annual fee. Additional costs can be incurred as a member decides to participate in a specialized area of technical service or support that may be offered.

Japan Nuclear Safety Institute (JANSI) www.genanshin.jp/

JANSI's mission is to ensure that the Japanese nuclear power industry pursues the world's highest standards of nuclear safety ("Untiring Pursuit of the Highest Standards of Excellence"). JANSI has the vision to drive forward nuclear operators' voluntary and continuous safety enhancement activities. JANSI works to specify bench marks of excellence for nuclear safety, and actively encourages operators to adopt these bench marks in pursuit of operational excellence. By evaluating nuclear facilities, JANSI also identifies gaps in comparison with standards of excellence and offers needed assistance to help close identified gaps.

Nuclear Procurement Issues Corporation (NUPIC) https://nupic.com/

NUPIC is committed to the future of commercial nuclear power. With a proven process for evaluating suppliers for high quality standards, NUPIC is the NRC licensee's preferred and cost-effective method of maintaining their approved suppliers List. NUPIC members include all domestic U.S. nuclear utilities and several international members. The NUPIC organisation will strive to improve the supplier assurance processes through cooperative efforts while minimizing utility operating and maintenance costs and improving plant performance.

Nuclear Energy Agency (NEA) www.oecd-nea.org/

The Nuclear Energy Agency (NEA) is an intergovernmental agency that facilitates cooperation among countries with advanced nuclear technology infrastructure to seek excellence in nuclear safety, technology, science, environment and law. The NEA, which is under the framework of the Organisation for Economic Cooperation and Development, is headquartered in Paris, France.

Nuclear Energy Institute (NEI) https://nei.org/

NEI's mission is to promote the use and growth of nuclear energy through efficient operations and effective policy. NEI accomplishes this by providing a unified industry voice before the U.S. Congress, the executive branch, state and local legislatures, and federal regulators, as well as international organisations and venues, on key policy issues.

Owners Groups:

BWR Owner's Group	BWROG	nuclear.gepower.com
PWR Owner's Group	PWROG	www.westinghousenuclear.com
CANDU Owner's Group	COG	www.candu.org
EPR Owner's Group	EPROG	www.framatome.com

(Note: There is no VVER owner's group)

Owners groups exist for different families of reactor designs, such as boiling water reactors, pressurized water reactors, or heavy water cooled reactors (CANDUs). They provide a forum, usually in conjunction with designers and manufacturers, where utility members can, for example:

- Achieve higher plant reliability
- Maintain and improve plant safety
- Minimize and share costs
- Facilitate regulatory interaction

Access to owner's group content and services are available via paid memberships. Membership is a fixed annual fee. Additional costs can be incurred if a member decides to participate in a specialized area of technical study or support that may be offered.

Russian Research Institute for Nuclear Power Plants Operation" (VNIIAES) www.vniiaes.ru

VNIIAES is an engineering company engaged in the development and technical support of worldwide nuclear energy projects based on the VVER reactor design technology. The company's mission is to provide world-class engineering solutions to achieve plant safety and efficiency goals. Technical support focuses on all stages of the plant's life cycle to include the development of nuclear infrastructure, site selection and design safety analysis. VNIIAES provides technical and operational experience and expertise. Focus areas include operations, maintenance, chemistry, plant system modelling and engineering calculations, component aging programs, radiation protection, and emergency preparedness. VNIIAES also provides support in the development of training simulators and technical leadership and services for the commissioning of newly built nuclear power units.

Women in Nuclear (WIN) www.win-global.org

Women in Nuclear Global (WIN Global) is a global organisation which supports and encourages women working in nuclear industries throughout the world, particularly energy and radiation applications. WIN Global aims to promote the understanding and public awareness of the benefits of nuclear and radiation applications through a series of active networks nationally, regionally and internationally. WIN networks are typically very active.

World Nuclear University (WNU) www.world-nuclear-university.org

The World Nuclear University (WNU) is a worldwide network of educational and research institutions engaged in peaceful uses of nuclear energy. It was inaugurated in 2003 under a Declaration of Commitment by 32 initial participants and four founding supporters.

WNU offers a range of unique nuclear educational and training programmes globally, organised by the WNU Coordinating Centre in joint collaboration with members of the WNU network. By drawing on the support of industry, governments and academia, these programmes are designed to meet the training requirements of international nuclear professionals, particularly in the area nuclear leadership.

Young Generation Nuclear (YGN)

There are a number of YGN chapters in different countries that provide opportunities for a young generation of nuclear enthusiasts to develop leadership and professional skills, create lifelong connections, engage and inform the public, and inspire today's nuclear technology professionals. Some examples include Young Generation of WANO, the North American Young Generation in Nuclear (https://naygn.org), or the Nuclear Institute Young Generation Network (https://www.nuclearinst.com).

By now, you should have concluded that you are not alone in your journey. We will take a moment to remind you that we are hostages of each other. Your success is the real concern of your industry colleagues; their success should increasingly become your concern. We end this section by strongly encouraging you to engage with the industry support entities discussed in this section. Additionally, lean heavily on your new operating colleagues within the nuclear industry to support and guide you, especially those known to be strong operators who share with you a similar plant technology, operating environment, or facility arrangement.

<u>Section G: Preparation for the First Cycle of Operation</u>

1. Transitioning the Organisation from Construction to Plant Operations
2. Fuel Receipt
3. Plant Startup to Full Power Operation *… to be developed for Roadmap Revision 1, 2021*
4. Outage Preparation

Transitioning the Organisation from Construction to Plant Operations

Moving an organization from plant construction to plant operation is an extremely difficult transition.

Before discussing the important questions of when, what and how, it is first important to understand that this transition will not occur naturally. The construction organisation will neither initiate nor promote this transition. Without the owner/operator actively driving the transition, nothing will happen. Even with strong support and guidance by the executive leadership of the construction organisation, there will be significant resistance to change in the workplace. In its enthusiasm to complete construction, the construction team will be very content to continue doing what it's been doing for the past several years. The construction team will resist any real or perceived loss of control of plant activities and be less than enthusiastic to invest time and energy into changing plant processes, programs and personnel behaviours. Regardless of how clearly your commercial contract provides guidance for this transition, expect organisational resistance to be very high and the execution to be extremely difficult. The transition to plant operation will serve as an early test of the operating team's leadership effectiveness.[29]

When should the plant and organisational transition to operations begin?

Ideally, an 18 month period of transition to plant operation will begin with the commencement of Hot Functional Testing (HFT). If you follow the guidance within the roadmap, the HFT will serve as a starting point for the use of operations personnel in the MCR and in the plant, the use of select operation's processes and programs, and the introduction of operational standards, protocols and behaviours within the plant. As a rule, as soon as the prerequisites for a specific operational process, program or protocol can be met, you should begin the process of introduction, implementation and transition. Your full transition from construction to operations should be complete before you host the WANO PSUR.[30]

What are the key areas of focus for the transition?

We will discuss the answer to this question in three parts – transition of the plant, transition of processes and programs, and transition of the organisation, (i.e. the people).

PLANT: The plant transition includes two primary tasks: the completion of system turnover to operations in accordance with defined standards and the verification of plant systems and components for operation. The following two scopes of work should be defined, scheduled and executed.

A system walk-down is the process of visiting a system installed within the plant and carefully scrutinizing all physical and environmental aspects of that. Each system should be walked down by a cross-functional team of operations personnel (i.e. operations, engineering, maintenance, chemistry). Component and system status should be verified against a defined operating standard. Deficiencies should be formally recorded and assessed using a graded approach. All deficiencies critical to safety and important to operations should be corrected before formal acceptance of a system by operations. The total number of specific, low-level deficiencies accepted by operations at turnover should number less than 20. More than this and the total backlog of deficiencies for all systems becomes excessively difficult to manage.

[29] WANO PO&C 2013-2 WANO Pre-Startup Performance Objectives and Criteria
WANO PO&C 2019-1 WANO Performance objectives and Criteria LF.1, OR.1-3

[30] WPG-06, WANO Pre-Startup Peer Reviews

Recommendation: The organisation will have enthusiasm to declare plant construction finished and commissioning complete. During system turnover, operations has the responsibility and opportunity to ensure it is receiving a high-quality plant. Your ability to verify this will be dependent on the quality of your system walk-down team. You are encouraged to carefully select the members of your walk-down team. Additionally, plan to conduct training with this team to create familiarity and understanding of your program standards for system turnover and the examples of plant, system and component deficiencies identified during recent WANO plant review activities

- The commissioning organisation will verify that components and systems meet the requirements of commissioning tests. Meeting regulatory requirements for plant startup requires that plant components and systems meet technical specifications for operability. The scope of operational surveillance tests will need to be complete before plant startup.

Recommendation: The organisation will have enthusiasm to declare the plant ready for operation. Carefully scrutinize all test results and all identified plant condition reports with an eye toward operability as defined by plant technical specifications. Given the potential inexperience of your operations team, you are strongly encouraged to engage an independent engineering team to conduct a careful review of final test results and condition reports to assess operability. High priority plant component and system issues critical to plant and personnel safety and system operability should be addressed prior to plant startup.

PROCESS and PROGRAM: There is a large scope of process and programs to be implemented within the plant. The logical sequence of implementing this scope should be captured in the operational readiness schedule.

The transition period of plant processes and program implementation really starts with the implementation of the WM process and plant schedule. The WM process supported by schedule and enterprise management software is the means of coordinating the identification, scheduling, preparation, coordination and execution of all plant activities. Operations uses the WM process and the schedule to understand, assess, approve and support plant activities. Once implemented, all other processes and programs (e.g. equipment tagging, maintenance planning, risk management, etc.) connect into and compliment the WM process and program.

Recommendations: To enhance the process and program implementation and execution efforts, we encourage the following:

- Create an Implementation Centre (IC). An IC is a centralized physical location staffed by a team of cross-functional SMEs and instructional personnel whose singular focus is to coordinate and execute the broad array of change management activities required for successful process and program implementation. The scope of these change management activities should include:
    - Verifying the approval, trial use, and subsequent revision of supporting documentation.
    - Support for end user navigation of the system of ERP, WM and supporting software.
    - The provision of hands-on worker coaching by SMEs.
    - Monitoring the progress of completing employee job familiarization guides (JFGs), to be discussed shortly.
    - The coordination of targeted field observations.

The IC will be responsible for the oversight, support and reporting of the implementation progress. A line manager for a particular process or program is responsible for successful implementation. That said, the IC is a tool to help facilitate the complex coordination of a large scope of change management activities. It is therefore in the best interest of responsible line mangers to endorse and support the activities of the IC.

- The scope of familiarization activities and training required to support the successful implementation of all processes and program is enormous. To successfully manage this challenge, the development and use of job familiarization guides (JFGs) is recommended. A JFG is a written document that defines the scope of process and program training and familiarization activities for each role within the organisation. The JFG serves as a checklist for an employee. Once defined, each individual filling an organisational role becomes responsible for completing the defined scope of specified reading, online training, practical exercises and formal training required for their role. As discussed in recommendation 1, the IC monitors organisational progress completing JFGs.

PEOPLE: The transition of your people’s hearts, minds and bodies to operations is your toughest challenge. The mind set of an operator is dramatically different than that of a constructor. Safe and efficient plant operation is the outcome of daily, error-free execution of operating fundamentals. Transition must focus on enhancing operating fundamentals - knowledge, skills and behaviours.

- Knowledge: Day-to-day participation in commissioning and operational readiness activities expands the knowledge level of all plant staff. Additionally, for plant staff in the core operating functions, participation in continuing training is essential to improving plant operational knowledge. The training department should have developed and implemented a structured and rigorous program of continuing training. Once initially trained and qualified, core operating staff should be immediately enrolled in and participate in continuing training. For MCR operators, important topics will include, 1) familiarization with plant design changes, and 2) the conduct of day-to-day normal operations (in contrast to the abnormal and emergency plant operations training the dominates the latter phases of training for initial qualification).

Additionally, a scope of just-in-time (JIT) training topics should be defined, scheduled and prepared for delivery. When properly planned and executed, JIT training can enhance individual knowledge, reduce operational anxiety, and enhance performance. JIT is particularly useful prior to the conduct of first-time evolutions.

- Skills: The organisation must be ready to demonstrate specific skills. These critical skills are called upon in the normal course of daily plant routines. Thus, plan to establish and execute key aspects of normal daily plant routines as soon as possible. Such routine activities should include:
  - Conducting plant rounds.
  - Writing and application of plant safety tags. (Note: Safety, or danger tags, indicate system isolation points that have been established to create a safety barrier for work activities. Safety tags are typically red.)
  - Executing the plant schedule, including the conduct of a daily schedule meeting.
  - Executing the CAP process to include conducting a daily CR screening meeting.
  - When events occur, conduct formal investigations and follow-on causal analysis and corrective action.

- When components and system performance issues arise, conducting troubleshooting activities.
- Conducting daily plant meetings (e.g. operations turnover meetings, staff plan of the day review meetings, etc.).
- Conducting formal plant management performance review meetings.

Rigorously conducting the above five items will routinely initiate the execution of and exercise important organisational skills.

- Behaviours: Nuclear professionals consistently demonstrate the correct operational behaviours. These behaviours do not happen by accident and must be carefully nurtured throughout the 18-month transition period. To achieve consistent demonstration of expected behaviours, the leadership team must do the following:
  - Define, explain and implement a comprehensive and detailed set of expected employee behaviours.
  - Model the desired behaviours and lead by example.
  - Regularly repeat the expectations and the bases for them -- explain the why.
  - Routinely observe employee performance.
  - Reinforce the correct behaviours when observed; address the wrong behaviours when observed.[31]

Recommendations: To enhance the leadership efforts noted above, we encourage the following:

- At the commencement of HFT, implement a formal management observation program in the field. At a minimum, expect each site leader (i.e. supervisor and above) and program expert to conduct a minimum of two formal observations monthly. Use the documented output of this effort to enhance worker knowledge, skills and professional behaviours, and to assess the organisation's progress toward operations.
- Focus on high risk and/or high impact areas of behavioural performance. Examples include FME, plant tagging, confined space entry, use of HU tools. Ensure that all related safety barriers and signage are professional, accurate and appropriately deployed and adhered to.
- Develop and implement dynamic learning activities (DLA) to establish or correct desired worker behaviours. See the discussion regarding DLAs in the Success Stories captured in Appendix 6. In the examples provided, proactive behavioural interventions are designed and executed to change employee behaviours. These behaviours are often common place and acceptable throughout the construction period, but now must change as we approach operation.
- Implement the WANO guidance for operation and engineering conservative decision-making. Initiate formal operational (ODM) and engineering decision-making (EDM) per the guidance as plant circumstances dictate.[32]

[31] WANO PL2012-02 Principles for Enhancing Professionalism of Nuclear Personnel
[32] WANO GL 2002-1 Principles for effective Operational-Decision-Making
WANO PL 2012-06 Principles for Maintaining an Effective Technical Conscience

Given earlier discussions within the roadmap, you should recognize the efforts described in the above section on people transition as an acceleration of efforts to develop a healthy nuclear safety culture.

How should the scope of the above be managed?

The vast majority of the items above belong in the schedule. Emphasize the need for schedule adherence and focus on daily schedule execution to complete the specified work scopes. Doing so will also foster schedule discipline within the organisation. This will serve you well in your efforts to achieve safe and efficient performance during plant commercial operation.

In addition, establish performance metrics to monitor the completion and completion rate of each of the work scopes defined above. These metrics should be kept up to date and accurate. They should be reviewed as part of the agenda during schedule review meetings. This practice will allow management to assess the level of progress in each area of transition.

Any final recommendations on transition?

Both individual and organisational proficiency are gained by doing. But not everything is readily doable. Some items will not be performed until plant startup and some items only occur in response to plant events. For these items, consider the formal development and execution of operational readiness exercises (ORE). OREs are intended to take the organisation through multiple types of practical exercises. These include process and program simulations, response drills, table top exercises, walk-throughs, simulator scenarios, and other practice techniques. These exercises can yield greater individual understanding, enhanced organisational proficiency, and help in the identification of issues to be addressed prior to operation. OREs are discussed in the Success Stories captured in Appendix 5.

Fuel Receipt

The receipt of nuclear fuel on-site is a significant milestone… but it is not an urgent one.

Depending on the originating location of your fuel vendor, the fuel receipt evolution includes the following major steps:

- Vendor fuel and cask preparation, packing and shipment
- Fuel transport
- Fuel receipt in host country
- Fuel transport in host country
- Fuel receipt on-site
- Fuel transport on-site to plant
- Fuel handling in the plant
- Fuel receipt and storage in the plant

All of the above incur some bit of nuclear risk. For a new nuclear country, this is a significant first-time evolution. While the reality of nuclear risk is low, the risk to reputation is high. Poorly executing this evolution – to include shipping delays, accidents during transit, a dropped cask or fuel bundle – can shake stakeholder and public confidence in your program.

While not urgent, getting this done well before fuel load is helpful for two reasons. First, the preparation and execution of the eight fuel receipt steps outlined above is a complex, first-time evolution for the operating organisation. It will require the engagement and coordination of personnel from a broad range of functional organisations. Preparation and execution for this evolution will require action by personnel from the fuels, licensing, operations, radiation protection, security, safeguards, nuclear oversight, communications, emergency planning and training departments. Fuel receipt will challenge the leadership team's effectiveness to foster teamwork in pursuit of event-free operation.

Second, the evolution will demand a significant amount of organisational time, energy and focus. The number of operationally important activities and the level of distraction from numerous sources will rise dramatically as you approach fuel load. Getting this evolution completed well before fuel load and the conduct of WANO and IAEA external assessments eliminates the risk of overlapping evolutions. The leadership team must align the organisation - a new organisation - to focus on conducting this important evolution without event. Assuming all of the plant, process, program and people pre-requisites are complete and verified, getting this done early prevents overlapping activities and allows for enhanced organisational focus and improved performance.

In the figure on the following page, we have provided a set of Operational Readiness Criteria for Fuel Receipt. Each of the listed criteria must be satisfied in a complete and quality manner. Formally document completion of each criterion. Subsequently, expend effort to independently verify the completion of each. Doing so is consistent with our mantra of "trust, but verify."

A word of caution: once preparations are complete and the evolution begins, the leadership team must avoid the real or perceived application of schedule pressure. Allow every individual to take the time he or she needs to do it right. The focus must be on doing each task correctly. How you lead the execution of this important first-time evolution will have a significant impact on the nuclear safety culture you are trying to create.

Once the evolution is complete, be sure to conduct a number of post-job critiques, or detailed reviews and performance assessments. Collect the input and take action to improve future performance. In doing so, you help set a standard for continuous learning.

Figure G.1 Operational Readiness Criteria for Fuel Receipt

The following criteria should be met, and verified prior to the initiation of the safe shipment, transport, receipt, handling and storage of new reactor fuel:

Plant Licensing:

- The completion of core design for first cycle of operation
- The development of a Probabilistic Risk Assessment (PRA) model
- The receipt from the nuclear regulator of permission or a license for fuel transport, receipt, handling and storage
- The receipt of non-nuclear permits in support of nuclear shipment and transport

Plant:

- The satisfactory turnover of all plant systems critical to fuel receipt and storage to defined operational standards. This includes receipt and verification of system design, component, vendor (e.g. Bill of Materials), and master data
- The satisfactory turnover of all plant areas critical to fuel receipt and storage to defined operational standards. This includes the fuel floor and relevant loading bay areas.
- The completion of satisfactory* commissioning testing of all plant components and systems critical to fuel receipt and storage
- The verification of plant component and system line up in preparation for fuel receipt and storage
- Supporting design, analysis, testing, construction completion, etc. documentation is turned over

*Note: Commissioning and startup testing needs to ultimately meet operability criterion for applicable safety systems

People:

- The staffing of personnel to targeted levels
- The training and qualification of the requisite number of personnel for each supporting organisational function
- The documentation and retention of all personnel training and qualification records applicable to the fuel receipt evolution

Documentation:

- The development, implementation and functional verification of all processes and programs
- The development, implementation and plant/simulator verification of all plant operating procedures

Supporting Infrastructure:

- The implementation and functional verification of all underlying safeguards related software infrastructure
- The implementation and functional verification of the underlying document and record retention program
- The completion and outfitting of all required facilities
- Complete and functioning security barriers and guard force capability specific to the fuel transport route and storage facility

Verification of Organisational Performance

- The conduct of operational readiness exercises to verify organisational effectiveness in support of fuel transport, receipt, handling and storage
- The conduct of satisfactory demonstration of emergency planning capability applicable to fuel transport, handling and storage
- The successful completion of safeguards inspection and assessment by the IAEA

Source: New Unit Assistance Working Group

Transition from shutdown to power operation

See revision 1 of the Roadmap in 2021

Outage Preparation

An outage is any period of time after initial plant startup and operation when a plant is not operating. There are two types of outages: planned and forced. A planned outage is a deliberately planned and scheduled period of time when the plant has been removed from service for maintenance and/or refuelling. A forced outage is the resultant period of time after an unplanned plant removal from service. Forced outages can occur after a plant transient or trip. A forced outage can also occur as a result of plant removal from service to address an emergent maintenance or technical issue. Outages will include system and component maintenance and testing activities as well as those operational activities that are prerequisites for startup. Planned refuelling outages will include a change in reactor fuel.

In this section, we will actually address three distinct outage challenges you must be ready to execute as part of operational readiness. The three outage challenges are:

- Conduct of your first planned outage.
- Conduct of a warranty outage at the end of PAT.
- Preparation for a forced outage.

High-performing organisations are very good at planning for and executing outages. The conduct of a thorough and rigorous process of outage planning and preparation, coupled with an organisation's ability to safely and efficiently conduct plant outage activities, is essential to achieving optimum plant short-term (i.e. annual) performance numbers. To assure longer-term performance, you will need to plan to complete a comprehensive scope of testing and maintenance work as defined by engineering and maintenance programs. To achieve short and long-term performance requires your organisation complete a conservatively determined scope of work safely and efficiently. To get excellent plant performance numbers, you must have strong outage performance.

Conducting your First Refuel Outage

So why are we discussing plant outages in a document focused on operational readiness?

Per the timetable discussed in Section D, your first refuel outage will occur as soon as 18 months after fuel load (and a mere 12 months after a shortened operating cycle post power ascension and achievement of commercial operation). While this may seem like ample time, the reality is that a robust process of planning and preparation for outage maintenance and testing activities starts long before the outage.

Your first refueling outage will include a large, complex scope of activities to include maintenance tasks, equipment testing, fuel removal and replacement, and the completion of operational pre-startup prerequisites. You will be executing this large scope of complex activities with a new and untested organisation. Early, thorough and rigorous outage planning and preparation will improve the potential for safe, efficient and timely outage execution. Failure to do so will certainly result in a performance disaster and raise the probability for mistakes and safety issues.

Refer to the figure entitled, Outage Planning Milestone Matrix. This matrix defines a typical set of milestones consistent with industry best practice for outage planning preparation.

Outage Planning Milestones Matrix				
Milestone	Milestone Description	Start Date (months)	Finish Date (months)	Owner
1	Pre-Outage Milestone Schedule Approved & Issued	30	24	Outage Manager
2	Identify and Approve Outage Modifications (C)	30	24	Outage Manager
3	Major Work Scope Identified (C)	24	20	Director, Engineering (Plant)
4	Complete Preliminary Outage Cost Estimate	18	16	Director, Finance
5	Engineering System/Programs Scope Identification	18	14	Director, Plant Engineering
6	Pre-Outage Organization Identified	18	13	Director, Outage Management
7	Identify/Submit all Licensing Changes, Regulatory Commitments, etc.	24	12	Director, Licensing & Regulatory Affairs
8	All Outage Modifications Designed (C)	24	12	Director, Engineering
9	Issue Rev "A" Schedule	16	12	Director, Outage Management
10	Review Initial Scope with Key Stakeholders, Freeze Outage Scope (C)	24	12	Outage Manager
11	Order Long Lead and Critical Procurement Materials	20	9	Director, Procurement
12	Complete Electrical Bus De-Energization Plan	9	7	Director, Operations
13	Determine Outage Work Scope Assignments	12	6	Director, Maintenance
14	Develop the Outage Chemistry Plan	15	6	Manager, Chemistry
15	All Outage Work Order Task Planning Complete (C)	15	5	Director, Maintenance
16	All Outage Material on Order - Exception List Implemented	14	4	Director, Procurement
17	Issue Outage Rev "B" Schedule	8	4	Director, Outage Management
18	Complete Detailed Contractor & Shared Resource Mobilization/Demobilization Curves	6	3	Director, Finance
19	Validate Final Refuel Outage Budget	12	3	Director, Finance
20	Outage Service and Labour Agreements	20	3	Director, Procurement
21	Perform Horizontal Reviews	5	3	Director, Outage Management
22	All Outage Procedures Revision Approved and Issues	16	2	Outage Manager
23	Identify Contingency Plans and Approved	14	2	Director, Outage Management
24	All Outage Material on Order and All Parts Onsite Ready for Issue (C)	10	2	Director, Procurement
25	Develop Preliminary Dose Estimate, Radiation Work Permits (RWPs) Approved/Final Dose Estimate Complete	9	2	Radiological Protection Manager
26	All Temporary Modifications ready to Implement to include Shielding Packages Ready for Installation	13	2	Director, Plant Engineering
27	All Outage Tag outs prepared and reviewed (C)	9	2	Director, Operations
28	Develop & Approve Outage Shutdown Risk Assessment (SRA) Report	5	2	Director, Operations
29	Complete Vertical Slice Reviews	3	2	Director, Outage Management
30	Complete All Readiness Challenge Process Meetings	6	2	Director, Outage Management
31	Issue Rev 'C' Schedule	3	1.5	Director, Outage Management
32	Complete Water Management Plan	6	1	Director, Operations
33	Complete Work Order Walk-Down	11	1	Director, Maintenance
34	Clearance Walk Downs and Technical Reviews Complete	8	1	Director, Operations
35	All Identified Pre-outage Work Completed	14	0.5	Director, Maintenance
36	All Work Orders Ready to Work (C)	11	0.5	Director, Maintenance
37	Issue Rev '0' Refuel Outage Schedule (C)	1	0.25	Director, Outage Management
38	Complete Outage Speciality Training	8	0	Manager, Training
39	Complete All Outage Lessons Learned and Outage Gap Analysis	0	2	Outage Manager

Table G. 1 Outage Planning Milestones Source: New Unit Assistance Working Group

The first thing that should jump out at you is that the scope of planning and preparation milestones begins two years (or 24 months) prior to the refuel outage. So, outage preparation for your first refuel outage should begin six months prior to fuel loading.

In the six months prior to fuel load, at a minimum you will be driving the organisation to complete preparations, training to ensure safe plant startup, hosting assessments and visits by your regulator, WANO, IAEA, and other interested stakeholders, and responding to their feedback. If in addition some part of your organisation is not dedicated to the orchestration of outage planning steps, you are already destined to poor and high-risk outage execution.

If you aren’t intimidated enough already, perhaps a quick statement regarding scope. We mentioned the scope will be large and complex. For awareness, your refuel outage scope will likely require and include all of the following and more:

- Typical critical path schedule of defuel and refuel activities.
- Scope of in-service testing and inspection activities defined by your IST/ISI programs.
- Scope of flow accelerated corrosion (FAC) tests if required based on secondary plant piping material type.
- 100% scope of eddy current testing.
- A containment integrated leak rate test (ILRT) needed to make the case by comparison to baseline for extension to 10-year periodicity.
- A full scope of local leak rate test (LLRTs) needed to meet a 30-month testing frequency without grace allowance.
- All plant technically specified refueling outage surveillance tests.
- The advised scope of turbine inspections by your turbine generator vendor.
- Any contractually required maintenance for large components.
- Any maintenance scope output recommended by your predictive maintenance program parameter indicating equipment issues (RCP, TG vibration).
- Scope of targeted preventive maintenance activities.
- Scope of outage only corrective maintenance activities.

The list above serves to reinforce the point that the scope of your first refueling outage will be large, complex and very challenging for your new organisation to execute. Early planning and preparation are your best lines of defence.

Conducting a Warranty Outage at the end of Power Ascension

This outage is typically contractually stipulated. It is typically different from your refueling outage by virtue of the following:

- The major scope of planned and executed maintenance, inspection and testing activities are performed by your EPC contractor.
- The total scope is much smaller.
- Occurs prior to commencement of commercial plant operation.

Accordingly, this effort is less intimidating but still challenging. Those challenges include the first time your organisation will deal with the nuclear safety risks tied to shutdown.

One additional point to be made here: Prior to any planned outage, use the cycle of operations continuing training scheduled prior to the outage to address important operations topics. For example, this training should include introduction to the scope of plant system and equipment modifications to be installed during the upcoming outage. It should also include operator simulator practice of the plant shutdown and startup evolution.

Though perhaps a bit shortened and abbreviated when compared to the scope discussed above, you will need to plan and prepare in a similar, systematic fashion.

Preparation for a Forced Outage

Operating a plant safely includes being prepared to effectively respond to the unexpected. This includes having a forced outage plan.

The work management organisation should have the following:

- A well-defined approach to preparing for and executing a forced outage captured in a governing document.
- A standby forced outage plan for each plant unit. This plan should include:
    - Multiple options for outage length. These options are typically something like:
        - A quick turnaround forced outage of 24 to 48 hours.
        - An intermediate forced outage of 3 to 5 days.
        - A long-term forced outage of 7 days or longer.

        These outages are determined by the triggering event. For example, if a component failure requires a 4-day repair then an intermediate outage would be declared. If there is no equipment damage and the cause of the trip is readily known and can be readily corrected, a quick turnaround outage would be initiated.
    - A scope of maintenance and testing items are defined using a graded approach. At a minimum, each potential maintenance or testing item is designated as either mandatory or optional.
    - The complete preparation of each potential forced outage item to include a standby work package, procedures, tagging and standby parts.
- A duty roster. This is a defined list of cross-discipline personnel that are to be called immediately in the event of a forced outage. These personnel are rapidly mobilized to man the Outage Control Centre (OCC) and begin execution of the forced outage plan.
- A regimen of engagement and communication concerning the forced outage plan. Plant personnel should be kept abreast of forced outage plans and preparations. Most importantly, this includes routine updates with the operations MCR team.

Our message to you: A significant scope of plant outage preparation is required before fuel load. To be operationally prepared for safe plant operation means having contingency plans and preparations made for both planned and unplanned plant outages.

Section H: Special Topics

1. The Challenge and Opportunity of Multiculturalism
2. Plant Operations in a Multilingual Environment
3. Managing Digital Control Systems (DCS)

The Challenge and Opportunity of Multiculturalism

First the good news, multicultural teams have proven the ability to outperform homogeneous teams. Therein lies an opportunity. Academic studies suggest that roughly 20% of multicultural organisations perform as such. A multicultural workforce can bring many benefits, to include a broader base of knowledge, experience and enhanced communication and personal interaction skills. When these benefits are properly leveraged, the potential innovation and teamwork characteristics of culturally diverse teams can result in outstanding performance.

Now the bad news. More often than not, multicultural teams have a tendency to perform worse than homogenous teams. Therein lies the risk. A multicultural team presents unique and fascinating challenges. A multicultural team operating a nuclear power plant cannot be a poor performing organisation – the safety risk is too high. Thus, a multicultural nuclear organisation must invest additional time, energy, effort and funds to create organisational effectiveness and achieve safe and efficient plant operation.

So what determines the success of a multicultural team?

A great many things, of course, but none as important as the effectiveness of the leadership team. Let us share some observations and lessons learned from the experience of managing a broadly diverse multicultural team.

Key observations:

- Multicultural teams are very often multilingual teams. See the next section on Plant Operation in a Multilingual Environment to gain insights to this topic.
- Some individuals relish a multicultural experience. They constructively embrace cultural diversity with a mix of tolerance, fascination and open-mindedness. They thrive in the environment. They learn to contribute in new and different ways professionally; they often learn and evolve as a person.
- Some individuals are intimidated and confused by a multicultural experience. They struggle to interact and communicate effectively. Their professional productivity wanes and their personal anxiety rises.
- Team motivation and functionality is a function of trust. Building trust in any organisation is a long and arduous experience. This is especially true in a multicultural organisation. The challenge is even greater when one considers that different cultures define trust differently.
- The level of trust achieved in a multicultural organisation can be very high or very low. Even after building an organisation with high levels of trust, it can be lost very rapidly during challenging times or in response to a troubling event.
- There exists in every organisation a capacity for employee concerns, predictions and rumours. This is especially true for multicultural organisations. Miscommunication, misunderstanding and a broader base of employee life and career experience can combine in a robust and creative rumour mill. Expect that rumours will be more fascinating, more troubling, more concerning and sometimes more entertaining.
- Functions staffed with a predominant nationality are more likely to demonstrate silo-type behaviour that can undermine cross-functional communication, cooperation and teamwork.

Given these observations, what needs to be done to harness the opportunity (and avoid the risk) inherent with a multicultural organisation?

Key recommendations:

What should each individual do?

- Read and study about the characteristics of the national culture.
- Take additional time to build relationships with each other.
- Be more patient.
- Take a breath. Build in a greater time delay in personal response to all interpersonal stimuli (e.g. public comments, emails). Allow yourself additional understanding and processing time.
- Be cautious to avoid making assumptions concerning someone else's intent.
- Ask more questions, and then listen more intently for the answer… and for the message behind the answer.
- Be careful to not compromise important substance in pursuit of agreement. Work harder to define the logic and basis of what is being considered and discussed, especially as it pertains to safety.
- Do take the time to evaluate potential adjustments in your approach to addressing concerns and problems. As appropriate, adjust your style.
- Work harder on personal communications and interactions. Examples include:
    - Conversations: (See next section)
    - Emails: Consider simpler messages with improved structure. Add diplomacy; subtract potentially disparaging or disrespectful content.
    - Presentations: Use pictures to amplify points and help create understanding.
- Create opportunities for people to share and explain their cultural norms with one another.
- Become an expert on the use of the HU tools.

What should the organisation do?

- Hire leaders with the skills and experience to lead multicultural teams, or the capacity to learn to do so.
- Hire personnel with the capacity to survive and thrive in a multicultural environment.
- Expect personnel to struggle. Screen people at the end of the employee probation period. Allow for the graceful exit of leaders and employees who cannot adjust to your particular circumstance.
- Train and prepare people by providing intercultural awareness training and interventions. Provide a briefing on your particular organisational circumstance prior to hire – thus preventing surprises upon arrival. Provide training during new employee training – solicit and answer questions openly. Provide follow-on awareness training and interventions regarding cultural

dynamics that impact communications, decision-making and behaviours. This is especially important for leaders. Ensure such training is integral to leadership development programs.

- Expand the breadth and skill set of your OR function to address your particular circumstances.
- Build demographic balance across all sizeable functions of the organisation. Prevent the formation of silos and the resultant isolationism that can undermine teamwork.
- Strongly promote the deployment and use of a robust error prevention program and the associated use of HU tools.
- Develop timely and rigorous event investigation capability.

What must leaders of multicultural teams do?

- First, acknowledge the new environment and recognize the need for different leadership. Naivety is the enemy and assures suboptimal performance and the creation of an unhealthy and unsafe working culture.
- Work hard to define the operating model and create the associated leadership messages to be used describing the model in simple terms and pictures.
- Invest additional time in gaining leadership team alignment around key decisions.
- Define expectations AND the bases for these expectations. As a rule, if you can’t explain clearly and accurately why something should be done a certain way, then don’t set the expectation.
- Allow for personnel privacy; communicate often, openly and transparently about all issues and employee concern.
- Employ dedicated listening sessions with groups of employees. Ask questions to seek understanding.
- As required, conduct timely, careful and effective event investigation. Communicate the outcome.
- Establish timely and rigorous protocols for personnel management issues.
- Take great effort to be fair and consistent in matters of personnel accountability. Take special care to prevent real or perceived favouritism (or negativism) for any particular group (e.g. host nation culture – any current nation of political concern).
- Create and execute a scheme of robust protocols for internal communications.
- Practice more effective presentation skills. Talk more slowly and use high-quality presentation slides.

You may have noted that most of the above recommendations are true for any organisation. The degree of focus and effort is the differentiator. The simple truth is that working in multicultural teams requires the very best effort of each of us in all aspects of interpersonal relationships. Leaders and individuals will be required to learn and grow personally and professionally if the organisation is to leverage the opportunity of a multicultural team.

Plant Operations in a Multilingual Environment

In support of our discussion on this topic, we again reference the circumstances at our plant of choice. The plant's home country arguably hosts the world's most diverse resident population. Citizens constitute roughly 15% of the population. The vast majority of citizens are fluent in English as second language. The balance of the country's population is broadly diverse. English is spoken adequately by most of the residents of the country. The host country has repeatedly demonstrated an ability to leverage a broad multinational, multicultural workforce to develop and successfully implement an impressive array of civic and private industry projects.

English is the chosen operating language for the project. It is the second language for > 80% of the workforce. English proficiency was identified as a unique and significant challenge to safe plant operation. This is particularly concern for the main control room (MCR) operating crews. While some level of similar circumstance exists at other nuclear power plants, the scope of this plants challenge is unprecedented. No previously known framework for addressing English proficiency at a nuclear power plant existed worldwide.

Multilingual environments present unique challenges to project execution and plant operation. Industry analyses of plant operating events always identifies communication errors as the primary common cause. An environment where many or most persons are working day to day in a second language amplifies the potential for communication errors and the occurrence of plant events. Addressing the plant's unique communication risk is essential to its efforts to build a healthy nuclear safety culture and the pursuit of event-free operation.

A plant must determine its operating language. This determination can be complicated by the scope and variety of languages spoken by the organisation and its contractors. The language of the host country is an obvious and important consideration. For new entrants relying on international support, using the native language may be less than efficient. But for a new entrant to utilize a second language, the local population and its potential base of local hiring must have a reasonable competency in the core operating language of choice. The operating language of an EPC contractor is also worthy of consideration. Contract provisions for language proficiency can create complexity and cost for the contractor. In an ever more integrated world, international cooperation and communication across borders is increasingly important. For our discussion, like our plant of choice we will presume that English is the chosen operating language and that this choice requires many employees and contractors to conduct day-to-day business in a second language.

Given the choice of a core operating language different than the native language of a large proportion of the organisation and its contractors, what needs to be done to ensure safe and effective communication throughout the organisation?

- Recognize that language ability impacts day-to-day plant communications critical to personal and plant safety. It also impacts an individual's ability to read procedures, understand emergency announcements, and to learn during training and subsequently pass basic examinations. Lack of language proficiency raises the probability of error.

- For the chosen operating language, establish a standard for language proficiency for every employee and supporting contractor. To accomplish this, use a graded approach as described in the section that follows.

- Incorporate a language standard into job descriptions as a hiring requirement. Define employment language requirements using the International English Language Testing System (IELTS) and International Civil Aviation Organisation (ICAO) language standards. Ideally, hire and contract all manpower to the core language hiring standards. Contracts should incorporate the language standard as a contractor assignment requirement.

- Assess and develop a <u>nuclear</u> English standard for your program. General English proficiency is insufficient for the key roles in your nuclear operation. Examples of such roles include operator roles in the MCR and roles on the Emergency Response Organization (ERO) team. The needed level of language proficiency is domain specific and requires the ability to communicate during changing situations in real time. General English tests do not have this capability. A nuclear English test needs to be developed for this purpose, and experienced language assessors are required to assess an individual's level of proficiency in nuclear English

- Whilst many language schools can support general English training, nuclear English will require a unique and specific curriculum. Employ a highly capable teaching staff (qualified and experienced working in ESP (English for Special Purposes) in addition to experience teaching English in industry.

- Set nuclear English as an expectation for all staff, to include native speakers. Native English speakers need to support the non-native English-speaking population. They must practice keeping their spoken language simple, clear and slow (and even modify their accent if required) to ensure an international audience can clearly understand what is being said.

- As needed, train individuals in the chosen operating language. This can take months, if not years, of part-time or full-time training. (Note that some individuals may never reach the desired level of language proficiency regardless of the amount of training they receive. In such cases, employment action of various kinds may be required.)

- Individuals from different English speaking countries can have multiple words or phrases for the same thing (e.g. flashlight versus torch, "Stop the pump" versus "Secure the pump."). Where multiple options exist, standardize the choice of words and phrases to be used by the workforce to reduce ambiguity. Consider a standard action verb list to be used in procedures. Build the desired nuclear English standard into your procedure writer's guide.

- Carefully and accurately standardize the verbiage and pictures on plant signage of all types. Target the level of language use on site and plant signage to the lowest acceptable language standard defined for your organisation. Incorporate these signage standards into plant staff onboard training of all types.

So, how does one go about defining a standard for nuclear friendly language proficiency?

To address this question, we will share the approach taken at our plant of choice. In 2017, efforts began in earnest to address the unique challenge of effective communication in the multilingual nuclear program and plant environment present. A seven step approach to problem resolution was executed as follows:

1. Hired a broad scope of language Subject Matter Experts (SMEs).

   English Language SMEs were recruited, hired and/or contracted to include 1) senior educators with UAE experience, 2) SMEs from other analogous industries to include the fields of aviation and oil and gas, 3) examiners with expertise in the IELTS standard, and 4) language assessors with experience with the ICAO. This collection of expertise and experience was assembled into a nuclear English team. The concept of nuclear English was created.

2. Selected, bench marked, and examined analogous experience in the aviation industry.

The aviation industry, with its focus on safety and its experience with the use of English in a multilingual operational environment, was identified as an appropriate benchmark opportunity. The lessons learned from the experiences of airplane cockpit crews, supporting ground personnel, and air traffic controllers proved extremely valuable.

A focused effort to bench mark the aviation industry and explore its approach to language was launched. The lessons learned from numerous airline industry tragedies fed the development of a plant Nuclear English program. Team members from both aviation and nuclear were able to interpret parallels and points of distinction within the information collected. Specific learning yielded the following sequence of actions:

3. Created an English language framework using the ICAO standard.

   The ICAO framework of language descriptors was referenced to help create a comprehensive framework and basis for the development of the following:

   - A nuclear English proficiency standard,
   - A nuclear English training curriculum,
   - A supporting nuclear English test (NET) methodology, and
   - An approach to the delivery of nuclear English teaching and learning.

4. Conducted a language assessment of all operating organisation procedures.

   An initial analysis of operating procedures was accomplished to determine the minimum reading and comprehension levels required by personnel using plant procedures. This analysis did two things: 1) helped define the English proficiency level required, and 2) served as a basis for determining the Nuclear English Standard. Note: Subsequent refinements to the procedure writer’s guide resulted in refinements to procedures and some adjustments to requisite English proficiency requirements.

5. Created a nuclear English proficiency standard to ensure safe and effective plant operation.

   A. A team of personnel with collective expertise and experience in plant operations, human factors, and languages conducted a comprehensive inventory of operational tasks to be performed by the organisation. For each task, an evaluation of the communication and decision-making required by both individuals and teams was performed.

      Each task was evaluated by degree of difficulty. Communication, and subsequent decision-making, that involved greater levels of technical complexity and/or the use of higher order diagnostic and problem-solving skills were ranked as having a higher degree of difficulty.

      Additionally, each task was evaluated for timeliness. Communication and decision-making tasks with time constraints were ranked as having a higher degree of difficulty than those without time constraint.

      An example: Compare a task of equivalent technical complexity performed by an engineer at his desk to that of an operator in the MCR. The operator would have a higher level of language proficiency required due to the potential need to make real-time decisions.

      Once each communication demand was assessed for degree of difficulty, categories were defined and graded from high to low. For each category, a safety basis was described.

   B. For each communication category, plant tasks and associated organisational roles were mapped.

C. For each communication category, the required degree of language proficiency was determined and IELT and ICAO standards and scores were designated. The scores became the basis for language assessment, training and testing.

6. Developed a complementary language proficiency assessment process.

   An assessment process was developed to address all forms of communication – reading, writing, verbal, and, most importantly, comprehension. Two standards were chosen and employed.

   - The IELTS: This is arguably the highest international standard for language proficiency assessment and testing. Personnel working at the plant who are non-native English speakers are required to demonstrate a suitable level of nuclear English proficiency using general IELTS assessment and scoring. IELTS testing is provided at approved testing centres worldwide.

   - The Nuclear English Test (NET): This is an internal exam, utilizing criteria used in the aviation industry for language proficiency. It is designed to test employees' English language proficiency in speaking and listening (regardless of first language). It assesses their readiness to use English in a specific operational environment.

7. Developed and provided quality nuclear English training:

   A range of training and development resources are provided to support employee development efforts to meet requisite levels of nuclear English proficiency. An on-site construction building was repurposed to provide a central location for nuclear English training and support activities.

With the definition of the world's first nuclear English proficiency standard and subsequent development of a nuclear English training curriculum, a supporting nuclear English test (NET) methodology, an approach to nuclear English teaching and learning delivery, and the later creation of the nuclear English development (NED) centre, the organization works thoughtfully and diligently to ensure that its multilingual staff has the necessary language ability to effectively communicate in support of safe and efficient plant operation.

Note: In early 2018, the Nuclear English team completed formal assessments of all plant staff using the Nuclear English proficiency standard provided on the next page. Initial assessment indicated that <20% of non-native English-speaking staff were adequately proficient. Eighteen months later, after a significant training and development effort and repeated formal assessments, over 85% of plant personnel had attained proficiency in the use of Nuclear English. This represented a significant risk reduction and helped strengthen the underlying safety culture.

Category Name	Cat	Category Description	Safety Basis	Required Positions	Task Examples (Illustrative)	General English (4 skills)	Operational English
Leadership and Plant Operations	A+	Individuals who debate, reason, and make conservative decisions based on Tech Specs in the MCR that will have a direct impact on nuclear safety Actively participate in complex problem solving, troubleshooting and diagnosis of plant situations Implement emergency operating procedures and employ advance core damage mitigation techniques	An understanding of precise meaning is required to interpret linguistically complex texts. The ability to accurately articulate the rationale for decisions that affect nuclear safety, during unexpected turn of events and/or abnormal situations.	• Shift Managers (SM) • Shift Supervisor (SS) • Shift Technical Advisors (STA) • Emergency Directors (ED)	• Determining compliance with Technical Specification and their underlying Safety Bases • Response to beyond design basis accidents • Determining component or system operability	**IELTS** **6.5** All 6 Reading 7	AND **ICAO 5**
	A	Individuals undertake tasks, decisions, and direction that lead to real time manipulation of active plant components Individuals who: **a)** Give SPOKEN/ VERBAL communications directly to or from the MCR, face to face, via radio or telephone. To include instructions, advice and/or report information **AND/OR** **b)** Touch, manipulate or test live plant. Leading to a change in plant configuration, impacting control of the plant or the plant status. **AND/OR** **c)** Set to work, train, provide oversight, give instructions and directions to individuals in either of the above **(a)** or **(b)** **AND/OR** **d)** Supervise individuals, give direction, reinforce standards and expectations, to include performing Pre-Job Briefs **AND/OR** **e)** Write Nawah procedures, communications or contracts	Individuals directly affect Nuclear Safety in real time. Communications errors can adversely affect decisions and actions in operating environment. Aviation industry standard for flight operations in International Airspace, applies to Pilots and Air Traffic Controllers.	**Positions in a) or b)** • Reactor Operator (RO) • Turbine Operator (TO) • Electrical Operator (EO) • Local Operator (LO) • ERO Role (Ref 1) • Station Chemist • Security Alarm Station Operators CAS/SAS • Security Operations Supervisors • Radiation Protection • I&C Technicians • PNSC members **Positions in c) or d)** • All Personnel fulfilling Nawah Head and above positions • Senior Specialists (or above) in NOS, HU, OR, NSC, • Specialists (or above) in Communications • All instructors and trainers • Procedure Writers	• Startup of Plant Component • Conduct of operations surveillances • Approve / authorize work • Take and analyze a chemistry sample • Provide personnel work direction, delivering pre-job briefs and coaching in the field • Deliver emergency instructions across the PA system	**IELTS** **6** All 5.5 Reading 6.5	AND **ICAO 4**
Nawah Employees & Plant Workers	B	Individuals undertake tasks, decisions, and directions that influence plant manipulation, status, decision making and direction **BUT** allow for both time delay **AND** formal approval barriers by Cat A personnel via formal process Individuals who: **a)**Touch, manipulate or test <u>isolated</u> plant **AND/OR** **b)** Provide written communications, technical opinions, and reports **AND/OR** **c)** Work to approved Nawah procedures and processes	Limited to tasks that may influence plant operation but allow for both time delay **AND** formal approval barriers by Cat A personnel via formal process Perform tasks on isolated (clearance) plant component	• Engineers • Maintenance (Excluding I&C) • Operations clearance OR procedure writers • All Nawah employees/ ENEC security	• Maintenance task on an <u>isolated</u> component • Prepare engineering operability determination • Conduct radiation survey • Prepare clearance tagging • Apply human performance tools. • Participate in pre job briefs. • Write condition reports	**IELTS** **5.5** All 5 Reading 6	N/A
Unescorted Access	C	Individuals undertaking general support tasks on BNPP site, have the ability to a) pass Plant Access Training and Behavioral Observation training in English b)Recognize, understand and comply with all standards safety signs, barriers, sirens and notifications c)Recognize, understand and comply with standard list of specific Nawah English phrases and direction e.g. “Stop”, “Evacuate”, “Assemble” d)Recognize, understand and comply with emergency and plant critical reporting requirements (face to face or using communications media) e)Understand and comply with need for constant escort requirements while in Protected Area / Owner Controlled Area	No plant component manipulation Capable of responding to emergency announcements Not required to adhere to a written continuous use procedure requiring place keeping	• Scaffold Builder • Cleaner • Shop craft • Rad waste compactor	• Build a scaffold • Lap a valve seat in a machine shop	**IELTS** **4.5** All 4 Reading 5	N/A
Escorted Access Visitors & offsite workers	D	Offsite contractors not located at BNPP Escorted access to BNPP for contractors and visitors	Escorted access to Nawah only	• Site visitor (Dignitary) • Technical expert (Visitor) • Support staff (canteen)	• Site visit	N/A	N/A

Figure H.1: Nuclear English Proficiency Standard

Source: New Unit Assistance Working Group

Managing Digital Control Systems (DCS)

Do not underestimate the potential for a complete loss of a plant's digital control system (DCS) and the operator challenge, organisational impact and plant consequences of such an event. Complete failures of the DCS have occurred during the commissioning and power operation of new units. This has resulted in unexpected plant conditions that have challenged inexperienced plant operators. Most serious, unintended consequences have included reactivity management issues including unplanned positive reactivity additions (e.g. control rod withdrawal, reactor coolant system temperature decreases) and/or the loss of reactor manual controls. New plant operating crews are seldom proficient in handling complex plant events similar to a loss of DCS.

The failure of the DCS is addressed in plant design analysis. That said, a loss of DCS poses significant operator challenges. The organisation must build defences to prevent such occurrences and be prepared if and when they occur.

Key contributors to poor DCS system performance include the following:

- A lack of a complete and/or quality DCS system health assessment monitoring program.
- Poor configuration management. DCS system configuration changes for controls and operating set points are much easier to implement than earlier technologies. A weak design authority or a lack of a proper and deliberate change control process can result in uncontrolled design changes and create latent system problems.
- Incomplete, untimely or a poorly executed maintenance programs that undermines long-term reliability of the DCS system and its components.

Key contributors to poor operator response to a loss of DCS include the following:

- Operating procedures provide less than adequate guidance to address the plant impact of a loss of DCS. Additionally, plant system and equipment recovery procedures are often incomplete.
- The scope of operator training to address a loss of DCS scenarios is not sufficiently comprehensive to create needed operator diagnostic and plant response and recovery skills.
- Operating crews lack proficiency controlling the plant from back-up panels when called upon during the loss of DCS.

At a minimum, it is recommended that awareness briefings and targeted training be provided to engineering, maintenance and leadership staff in the proper monitoring and maintenance of the DCS and the proper response to a DCS system failure. Additionally, operator classroom and simulator training are recommended to prepare MCR operators in the proper response to a loss of DCS.[33]

[34] IAEA NP-T-1.4 Implementing Digital Instrumentation and Control Systems in the Modernization of Nuclear Power Plants

<u>Conclusion: Implementing the Roadmap to Operational Readiness</u>

Hopefully you have gained perspective and valuable insight from the review and reading of the "Roadmap to Operational Readiness." Now what? Let us take a minute in concluding to discuss some thoughts about putting this document to work for you and your organisation.

Each step below should be completed in the time frame recommended. Where reviews are suggested, each recommendation or element suggested should be rigorously reviewed. The determination for either the inclusion or rejection of any recommendation or element should be formally documented. Executive review and approval of the final disposition of each item should be conducted. The basis for any recommendation or element rejected or deemed not applicable should be particularly well scrutinized and challenged.

Prior to project phase 3: Commercial Contracting, perform the following:

Step 1: Evaluate operational considerations for your project and program

A. Review Appendix 1: Operational Considerations during Project Evaluation, Contracting, Construction and Commissioning. Consider each for potential decision-making and action. Where appropriate, this should include a review of previous decisions taken.

B. Decide what actions you will pursue. Commence formal action tracking.

Two years before FCD, commence the following:

Step 2: Take some immediate actions

A. Assign this document as required reading to key members of your staff.

   It is recommended that very early in the project development phase this document be read by the essential leaders of the organisation to gain insights and develop a deep respect for the task and journey to operational readiness that lies ahead. Going forward, consider assigning this document as required reading for all newly hired managers.

B. Complete some important quick win activities (i.e. activities that can be implemented and add value quickly). There are a number of smaller but impactful items that can be accomplished very early. Examples include:

   i. Develop and implement a Procedure Writers Guide

      Do not put pen to paper to write formal, controlled guidance documents until you complete this simple step. Doing so will leave you vulnerable to the inefficiencies and associated high costs that come with procedure writers doing as they please. Save time, money, and organizational frustration by defining detailed, document standards upfront.

   ii. Develop and implement a bench marking procedure document.

      This document will guide the actions your staff will take to explore the industry. It should provide a systematic approach to planning and execution of these efforts. It should help hold participants accountable for reporting, evaluation and implementation of selected improvement actions.

   iii. Develop the essential policies outlined in Appendix 2d.

      Define policies to provide the organisation guiding principles and specify applicable governing regulations. Using your benchmarking guide, encourage targeted efforts to bench mark sister station documents with the intent to improve the quality and accelerate the progress of your effort.

C. Identify and plan how to leverage your reference station.

Consider establishing relationships and potentially memorandums of understanding (MOUs) to gain valuable support and assistance.

D. Establish the milestone date for the start of hot functional testing (HFT)

This date, and the supporting schedule outlined in Section D, should guide the organisation toward your first significant milestone. In addition, use the criteria outlined in section D to:

i. Establish your criteria for achieving an interim level of operational readiness at the first concrete date (FCD)

ii. Establish your criteria for achieving an interim level of operational readiness at the start of HFT

This effort should help create a sense of urgency for the operating organisation.

Step 3: Conduct workshops to create leadership team and organisational understanding and alignment

It is envisioned that a number of facilitated workshops be conducted using this document as a guide. To illustrate this approach, initial workshops might be arranged into five discrete topics as follows:

- Introduction to the “Roadmap to Operational Readiness”
- Prioritizing Nuclear Safety
- Your Operating Model
- Planning Your Journey to Operational Readiness
- Leveraging Industry Support

It is recommended that a facilitator, an industry peer with relevant new unit, operational experience, and select support staff be carefully chosen and engaged to guide your exploration of this guidance.

Later, the above workshops can be repeated (and/or expanded upon) with the growing membership of your nuclear organisation. The above discussions should provide essential support to define your vision of an operating model, to determine a timetable for expected progress, and develop a schedule for your journey toward operational readiness.

Step 4: Develop an integrated plan for engaging industry support

A. Review the guidance provided in Section F: Engaging Industry Support. Determine those relationships critical to your operation. Reach out and identify key representatives of these organisations. At a minimum, WANO and the IAEA should be engaged. Start the process of building relationships.

B. Identify the most relevant and important industry bench marking opportunities for your project. Utilize WANO, the IAEA, EPRI and the owner’s groups to help highlight the best opportunities.

Similarly, refer to the roadmap's Appendix 5: Success Stories to help identify relevant opportunities for your project.

C. Create an integrated plan of industry support. Conduct a joint session with both WANO and the IAEA representatives to create a 10-year plan of engagement. This plan should be an integrated approach that plans and schedules all assistance and assessment activities. This effort is intended to optimize the support you receive while minimize overlapping efforts.

Step 5: Referencing Section C, define your operating model

A. Select your operating model architect(s).

B. Review and answer the balance of questions outlined in Section C.

C. Develop, document and approve your operating model. Immediately begin the process of communication, familiarization, discussion and implementation. Teach and align the organisation to your model.

D. Define your end state plant organisational structure. As required, consider how the phases will be implemented over time.

One year before FCD, commence the following:

Step 6: Referencing Section D, define your journey and schedule

A. Create an operations program management office (PMO).

B. Build a comprehensive Level 1 and 2 operational readiness schedule.

C. Define critical schedule milestones.

D. Develop and implement schedule performance management metrics.

E. Begin the process of building an accountable organisation. Reinforce organisational expectations for schedule adherence, corrective action completion, and overall project delivery.

F. Develop a comprehensive communication plan with emphasis on internal communications. Emphasize the organisational mind-set shift and associated behavioural changes required as you progress from construction to operation.

At FCD:

Step 7: Execution

A. Execute your daily schedule. Conduct regular schedule review meetings.

B. Complete identified corrective action program (CAP) actions including all planned assistance and assessment follow-up actions.

C. Verify business plan objectives are being achieved (if and when developed and in use).

Step 8: Formally monitor organisational performance

A. Monitor performance in the areas of schedule adherence, staffing totals and rate, procedure development and approval totals and rate, and CAP overdue actions. Review the indicators for each regularly.

B. Evaluate organisational progress toward key milestones by assessing status against the criteria defined for each milestone.

C. Routinely assess your evolving safety culture. Monitor the organisational mind-set shift and associated behaviour changes required as you progress from construction to operation.

D. Conduct formal management performance reviews.

APPENDICES

1. Operational Consideration during Project Evaluation, Commercial Contracting, Construction and Commissioning
2. Operating Model Essentials:
    a. Recommended List of Functions
    b. Recommended List of Processes
    c. Recommended List of Programs
    d. Recommended List of Essential Documents
3. Operational Readiness Planning Timeline - Basis
4. Operations Organisation Staffing Curve - Basis
5. Industry Success Stories
6. Master Reference List

Appendix 1: Operational Consideration during Project Evaluation, Commercial Contracting, Construction and Commissioning

The roadmap focuses on preparations for plant operation – a latter phase of your project. But, numerous decisions with significant operational impact are made during earlier project phases. Decisions during project evaluation, commercial contracting, construction and commissioning often have a near-term focus with less than adequate consideration on the impact on the next 100 years of operations. Poorly informed decision-making during early project phases can lead to safety concerns and have significant impacts on operational effectiveness, efficiency and costs. Smart decisions and minor expenditures early can have a dramatic long-term performance impact on your business.

The following list of operational considerations is provided to enhance decision-making during the earlier phases of your project with the intent to positively impact long-term operational performance. All that follows is intended to help you become a more informed owner and operator, a more intelligent customer.

Operational Considerations during Project Evaluation:

As part of your process of evaluating the possible initiation of a new nuclear project in your company and country, consider the following:

1. As the owner, you will be the construction licensee. Though you may be authorized to delegate certain responsibilities, you will always be accountable for safe plant construction (and eventually operation). Thus, you must fully understand your operational obligations and responsibilities as the owner. Accordingly, your standards and expectations should be defined, understood and embraced by the entire organisation. Personnel should be empowered to engage, insert, influence and/or enforce your standards and expectations to ensure that design, installation, testing and material quality is achieved prior to assuming full responsibility for plant operation. Be the standard bearer. Model established standards and intrusively enforce them throughout all project phases.

2. Even if you adopt a role as host country for a BOO (Build, Own, Operate) approach to your new nuclear program, the above applies. Remember, while a BOO contractual arrangement might help you avoid some of the fiscal liability of a nuclear accident, you will always retain accountability for the physical consequences of an accident to your country and its people. In all circumstances, you should establish an effective nuclear oversight capability. Effective oversight is perhaps even more important when employing a BOO approach to new nuclear.

3. If you are a new nuclear entrant, avoid the significant risk tied to First of a Kind (FOAK) plant technologies. Additionally, take care to avoid FOAK features in your new plant design. Your plant will likely need plant modifications to address local environmental conditions that differ from that of the reference plant. Additionally, your reference plant may have identified design flaws that you would like to address. In both cases, correct these issues using simple designs and proven components.

4. The evaluation of your nuclear project must accommodate both the plant you plan to build and the operating mode you plan to use. While you are unlikely to have defined the entirety of your operating model prior to evaluation, some critical questions should be asked and answered in order to conduct a more thorough, realistic and accurate project evaluation. This initial determination should include definition and understanding of the following:

    a. Regulatory model and regulator expectations.

b. Electric transmission systems requirements and operational demands (e.g. will your plant serve as a base load or be expected to routinely change power levels).

c. Environmental standards for the plant’s operating environment.

d. Availability and competency level of local populations for potential staffing.

e. Plant and site operational security threats and requirements.

f. Detailed site characterization. This should include an assessment of site seismic conditions, the plant operating environment, and site location within the country.

g. Allowances for the incorporation of SOER recommendations.

h. Intent to utilize the practice of online maintenance (i.e. the use of license technical specification allowances to voluntarily remove redundant plant component or system trains from service with the intent to perform proactive maintenance activities). Use of such practices can have a significant positive impact on planned outage durations and thus expectations for project and plant performance yield.

i. Fuel types planned for use and the desire for an option to use alternate fuel types (e.g. MOX fuel).

j. Social demands and expectations.

k. Revenue/profit model (engineered enhancements such as pre-installed access platforms and remote data gathering to reduce operating costs vs. larger support staff for routine operations and support such as scaffold building to reduce upfront capital costs).

All project evaluation considerations should be incorporated into the commercial technical specifications to serve as the basis for tender.

Operational Considerations during Commercial Contracting:

Project contracting is an important phase of a new build project. The owner and contractor have the opportunity to define scope, expectations for deliverables, and operational standards to be embraced. The more clarity that is defined and understood, the less the potential for future surprises and contention. Unclear understanding of operational requirements between the owner (and future operator) and contractor can and has led to commercial disputes with significant impact on project costs and schedule. Alignment around clear operational expectations and standards can improve project quality, productivity, and minimize and/or eliminate risks.

Before going on, let us emphasize that safety must be your overriding priority. As owner, you must communicate your desire for, and commitment to, contracting, constructing and commissioning a safe and reliable operating nuclear power plant. While important, schedule and cost must not be the priority.

The items listed below need to be clearly defined between the owner and contractor(s):

1. Project Oversight Role

   Role clarity is important especially as it pertains to project oversight. Specify the depth and breadth of planned project oversight to be created and used by the owner. This should include specification of the following owner and operator rights and authorities:

   a. Access to all field and factory activities as well as all relevant findings and information. The right to ask questions and receive timely and accurate answers.

   b. Authority to exercise both immediate, infield stop work directions and formal stop work orders (SWO) in the event of safety and/or quality concerns.

   c. Involvement in all event investigations and analyses. The right to engage external, third-party consultants to conduct parallel, independent analysis.

   d. Intent to report non-commercially sensitive events and issues to external stakeholders to include WANO and the IAEA in accordance with reporting expectations.

2. Project Deliverables

   Set clear expectations for and the type, form and content of all project operational deliverables, and specify them within the contract. The quality, form and schedule for the receipt of operational deliverables must be carefully specified. The deliverables we will discuss include procedures and plant data.

   a. Your plant operating procedures are the foundation of safe plant operation. As the owner, you need to establish a high standard for procedure quality. A new plant with new, and often inexperienced operating staff, needs accurate and clearly written procedures with high degrees of specificity. Unfortunately, you should expect what you receive from a vendor to be far less than that needed and or desired. The reasons for poor procedure deliverables include, but are not limited to:

      i. Varying expectations for the level of procedure specificity.

      ii. Differences in variance between source location procedure and yours.

      iii. Differences between you and your vendors' procedure writing guide standards.

iv. As applicable, the negative quality impact that always accompanies the distortion that comes with language translation.

For your procedures, specify:

i. The scope of plant operating procedures.
ii. Both early and required delivery dates.
iii. Operating language.
iv. A specified native file format to enable immediate and easy use (e.g. Microsoft Word and not an Adobe Acrobat PDF file format).
v. The delivery of design basis documents for your plant operating procedures, especially for emergency operating procedures (EOPs).

All plant operating procedures will need to be walked down and verified against the plant as constructed (e.g. valve tag nomenclature). Your operational readiness schedule should allow for this. Delivery of the plant specific simulator well in advance of operator training will allow testing and verification of operating procedures in parallel with construction completion.

Given your need for high-quality plant operating procedures and the challenges outlined above, timeliness of procedure receipt is critical to your success. Early receipt allows you time to review and revise these documents to your standard. You are encouraged to consider contract incentives for early procedure delivery and significant penalties for late receipt.

b. For non-plant operational procedures (e.g. operating model policy, process and program documents) consider the purchase of a suite of operating model documents. Do this ONLY if the targeted operating model is:

   i. Supportive of the highest operating standards.

   ii. Compatible with your IT operating systems (e.g. SAP).

   iii. Written in an acceptable language.

Should you choose to purchase these, there will be time and cost associated with procedure revisions required for your plant, people, systems, language and environment.

If pursued, be advised that significant effort will be required to adopt, adapt, understand and implement operating model documents.

c. Plant data from various sources will be required to fill the demands of:

   i. Operations procedure preparation and verification prior to plant use.

   ii. Maintenance planning work packages.

   iii. Plant work scheduling efforts.

   iv. Input into the various software modules and data fields in support of design, licensing and equipment reliability programs.

Data sourced from vendor component and plant design documentation can be specified for delivery similar to that above for procedures. Data sourced from plant installation and testing will be dependent on the execution schedule for plant construction and commissioning. For this data, a data gathering process and turnaround time should be specified. The complete scope of your data to complete your data architecture should be specific as follows:

i. Defined data architecture and linkages.

ii. A specified file format that enables immediate and easy use.

iii. Specified format for data and associated metadata (i.e. data about that data).

iv. Delivery media form (e.g. Microsoft Excel vs Adobe Acrobat PDF).

v. Potential for, and specifications for online file access and sharing.

Where applicable, consider including all the above procedure and data specifications into the standards and criteria established for successful plant system turnover to operations. In other words, never accept any system, structure or component without the data and procedures needed to maintain and operate it.

You will have a need for access to program and plant software source codes. Vendors are always reluctant to share these for commercial reasons. Consider creating a contingency by requiring that the vendor deposit your source code to a bank safe or legal office which can be retrieved by the operator should specified conditions be unfulfilled or in the event of vendor bankruptcy.

d. Spare parts will be needed for your facility - some large, many small. You will need to specify the following:

   i. The proper scope of parts should be carefully bench marked to understand the appropriate cost and content of your inventory to assure safe and efficient plant commissioning and operation. Such inventory should account for the support of shops, training facilities and simulators as well.

   ii. Large-scale spare components should be purchased and thoughtfully staged within the plant or protected area confines to allow rapid utilization if required. A long-term component preservation and preventive maintenance program will be required to maintain the integrity and future functionality of these components.

   iii. Besides parts, the support of plant systems and components often demands specialized tooling. The scope of technical instruments and maintenance tooling should be scoped, purchased and outfitted. Such equipment may require vendor training support.

   iv. Warehouse specifications must allow for local environmental conditions. Factors like site location, airborne particulate, the highs and lows of temperature, humidity, etc. will impact the design and features of your warehousing facility.

> Caution: In the event your contract specifies a monetary allotment for spare parts, carefully scrutinize the proposed scope of materials suggested to satisfy this allotment. There will be incentive for your EPC contractor to provide you available spares versus needed spares. Consider engaging an external technical contractor early in the process to conduct an in-depth assessment of the proper scope of needed spare parts based on plant design requirements, preventive maintenance frequencies, and other technical factors.

3. Differences in external agency standards and expectations.

Your construction entity is familiar with the standards, regulations, codes and expectations of the external stakeholders in their country – not yours. Even when the words are the same, the understanding, application and implementation of such may be dramatically different.

a. Evaluate the differences between the philosophy, approach, standards and expectations of the nuclear regulator in your constructor's country and your local regulator.

   Example: Preparations and support infrastructure to satisfy a regulator with a safety case-based approach versus one with a compliance-based approach will be different.

b. Evaluate the differences between the philosophy, approach, codes and standards, and expectations between other regulatory bodies in your constructor's country and your local regulator.

c. Evaluate the differences between the philosophy, approach, standards and expectations between the WANO centre for your constructor's country of origin and the regional centre to which you intend to affiliate. Example: Differences in the interpretation, understanding, and implementation of standards related to a systematic approach to training (SAT) can and has created difficulties and additional work. The impact will vary based on the extent to which your training program's SAT basis would be assessed by your regulator or challenged during future training accreditation efforts you might intend or be required to undergo.

4. Probabilistic Risk Assessment Level 1 and 2

Industry best practice for the management of nuclear safety-related risks has evolved from the exclusive use of deterministic safety analysis methods (i.e. engineering judgements based on plant data). Probabilistic risk assessment (PRA) is now used to determine the risk of plant operation. PRA assigns accurate probabilities and real numbers to the probability of occurrence and the consequences of nuclear events. PRA provides insights into the strengths and weaknesses of the design and operation of a nuclear power plant. There are three levels of PRA definition. Your contract should provide for at least the first two levels.

a. Level 1 PRA: Estimates the frequency of accidents that cause damage to the nuclear reactor core. This is commonly called core damage frequency (CDF).

b. Level 2 PRA: Starts with the Level 1 core damage accidents, estimates the frequency of accidents that release radioactivity from the nuclear power plant.

c. Level 3 PRA: Radiological consequences of plant release.

Your PRA will be a function of your specific regulatory requirements.

The use of probabilistic analysis allows analytical justification for the development and use of optimized nuclear safety techniques. Development and use of such techniques are a significant undertaking but can significantly optimize the operating performance of your new unit(s). Examples include:

- Increased time allowance for safety-related recovery actions or operator actions required to comply with technical specifications. The justification for time and action can assist in the safe and efficient management of the plant when technical issues are discovered, or unexpected events or issues occur. This additional flexibility can help maintain plant operation and limit thermal transients.

- Reduced system testing and inspection requirements by applying probabilistic methods to analyse the likelihood of surveillance test failures.

- The opportunity to justify continued plant operation by applying probabilistic methods to analyse real-time plant risk to core. An example: A planned emergency diesel generator outage is in progress. An unrelated emergent plant safety-related component failure occurs. PRA can be used to calculate the total new risk to the reactor core and provide information for decision-making regarding continued plant operation and the conduct of the EDG maintenance. In such a scenario, deterministic methods might dictate the immediate completion of the EDG outage and/or shutdown of the plant.

5. Incorporation of Significant Operating Event (SOER) Recommendations

   Your plant’s ability to address the requirements tied to 17 significant operating events (SOERs) will be assessed and must be satisfied prior to startup. Some of these requirements include physical plant accommodations. Your contract should require the satisfaction of SOER requirements. Significant examples include:

   d. Requirements for transformer gas monitoring linked to SOER 2011-1 “Large Power Transformer Reliability.”

   e. Requirements for spent fuel pool alternative cooling capabilities linked to SOER 2013-3 “SOER 2011-3 “Spent Fuel Facility Degradation, Loss of Cooling or Makeup.”

   f. Requirements to evaluate the need for, and provide accommodation to address design basis accident assumptions linked to SOER 2013-2 “Post-Fukushima Daiichi Nuclear Accident Lessons Learned.”

   g. Requirements to design protection against open phase events linked to SOER 2015-1 “Safety Challenges from Open Phase Events.”

   h. Plant owner groups for PWR, BWR and CANDU plants typically have valuable insights and information regarding actual and planned plant accommodations for SOER requirements.

   Also review WANO and INPO best practice documents for recommendations for plant design. These documents include:

   - INPO 16-005, International Materials Aging and Degradation Bench marking

   - INPO14-001, International Equipment Reliability Benchmarking Report

6. Plant Construction with materials that support improved long-term operation:

   a. Plant components within the primary system should not be made of material that, when irradiated, are prone to the creation of significantly higher radiation fields (e.g. primary system components should not be made of the material stellite).

   b. Review and consider the National Academy for Corrosion Engineers (NACE) standards for corrosion and material selection. Some material choices can be cheaper and/or easier to install initially, but can lead to challenging operational conditions and significant future expenditure. Such decisions are often beneficial to the constructor but consequential to the owner/operator. To illustrate, while cheap to install, epoxy coated carbon steel in high salinity environments (e.g. emergency service water (ESW) systems using sea water heat sinks) has proven to delaminate and corrode quickly. High maintenance costs and early and costly replacement of a critical safety system piping financially makes no sense.

   c. Ensure material selection includes criteria for resistance to well-known phenomena such as stress corrosion cracking and erosion/corrosion.

d. Consider pursuing regulatory allowance for the use of plastic piping in certain plant applications where corrosion concern is high and system temperatures and pressures are relatively low.

7. Plant construction with accommodations to support operational efficiency:

a. Install plant components that allow for ready equipment monitoring and inspection. Inspection windows and access nozzles on plant components can accommodate improved operator inspections, more efficient troubleshooting efforts, and/or allow for the use of remote monitoring equipment. When used properly, these capabilities can enhance both the cost and effectiveness of your plant equipment reliability and maintenance programs.

b. Identify and specify the following plant features to improve the safety, effectiveness and efficiency of day-to-day plant operations and maintenance:

i. * Permanent ladders and platforms for ease of plant component access and operation.

ii. * Component rigging points and/or installation of permanent small-scale overhead cranes.

iii. Adequate plant system component isolation points in support of maintenance activities.

iv. * Fixed plant mounting of heavy tooling in proximity to future maintenance activities.

v. The infield staging, mounting and appropriate preservation of large-scale replacement components (e.g. spare transformer, replacement pump).

vi. Allowance for refuel outage permanent and temporary electric power inside and outside of containment.

vii. * Plant scaffold storage inside and outside the plant contamination zone.

viii. * Identify and install high-quality camera capability throughout the plant. Cameras in high radiation areas should be protected from the effects of irradiation to preserve their useful life.

ix. Adequate maintenance repair spaces, laydown areas, and material staging areas; consider staging warehouses that cross the protected area boundary (i.e., the protected area boundary runs through the warehouse) to make material and parts transfer more efficient while making the transfer more secure and efficient from a security standpoint.

* Complete and exact specification for each of these items may be difficult. Consider the use of a contract allowance of constructor time, effort and money in support of a projected scope of work. Future plant walk-downs by staff SMEs can identify the appropriate scope of work desired.

c. Consider employing a site and plant design specification strategy that exclusively uses above ground piping and cabling runs. This practice, while potentially unsightly, can eliminate the threat of environmental and logistic challenges tied to buried pipes and cables. Safer, more maintenance friendly performance can result.34

d. Consider the initial installation of light emitting diode (LED) lighting. When evaluated properly, installation of LED lighting can provide improved lumens, is cost neutral, and most importantly, provides the following benefits:

    x. Reduces operating cost of house electrical loads.

    xi. Reduces maintenance hours and activities tied to periodic light replacement.

    xii. Reduces radiation dose to personnel... especially for lighting maintenance in containment.

    xiii. Reduces the amount and associated cost of radioactive waste.

8. Provide adequate wireless communication capability in support of plant operations.

   Plant announcement systems are often inadequate in high noise areas. This problem increases as the plant comes alive and components and systems become operational, creating significant background noise. A contract allowance for the evaluation and subsequent installation of high-quality communication equipment throughout all areas of the plant should accommodate use of high-quality radio and/or cell phones. Bench mark efforts should readily identify best practice communication equipment.

9. Equipment reliability

   a. Define and create a robust and plant-specific equipment reliability process and supporting database. Engage contractors early to specify desired data formats and the supporting database configuration.

      After equipment installation and commissioning, your maintenance effort will include the conduct of preventive and predictive maintenance program activities. The data you collect and store must be sufficient to support the planning and execution of these maintenance activities.

   b. Use a graded approach and designate plant systems and components by safety classification. Component safety classifications inform design and manufacturing specifications, environmental qualification, QA requirements, etc. These classifications should be done with caution and great attention to detail. Lower than appropriate classifications can lead to eroded plant safety margins, while higher than required classifications can lead to increased costs. The output of this exercise will have significant technical and financial consequence. Given the significance, consider engaging a third-party verification effort.

   c. Require that all plant single point vulnerabilities be assessed and identified for your plant design and installation. At a minimum, update your equipment reliability program database with this information. Use this data to inform your future scram reduction efforts. Where possible, consider plant design changes to eliminate any identified vulnerabilities.

[35] INPO 16-005, International Materials Aging and Degradation Bench marking, dated May 2016

10. Plant system turnover

    Standards need to be defined for system turnover from construction to commissioning and then again for system turnover from commissioning to operations. These standards should be defined in detail. Bench marking (or purchasing) a rigorous turnover process with detailed standards specified and subsequently referencing the associated documents in your contract is recommended. Use WANO to identify ideal bench mark candidates.

11. Operating procedures

    In addition to our earlier discussion on procedure deliverables, we provide some additional thoughts specific to various types of plant operating procedures. Consider the following:

    a. Emergency operating procedures (EOP) are developed using one of two types of initiating circumstance. Symptom-based procedures trigger action when a specified plant parameter is met or exceeded (e.g. low reactor water level). Event based EOPs are triggered upon the occurrence of a particular plant circumstance (e.g. reactor coolant pump trip). Specify that the emergency operating procedures (EOPs) provided be symptom based. A symptom-based approach to EOPs is the international standard endorsed by the IAEA and most reactor vendor owners' groups. Unfortunately, some vendors continue to supply event-based procedures. Event-based procedures, while satisfactory, often undermine operator training and understanding. Less than adequate plant operation can result. Plants that later rewrite their EOP procedures in symptom-based format improve their operator performance, but do so at great time and cost. See the relevant industry success story included in Appendix 5.

    b. Incorporate post-Fukushima lessons learned and develop and implement the Severe Accident Management Guidelines (SAMG and SAM procedures) which incorporate the use of FLEX equipment. FLEX equipment is plant equipment that has a defined secondary use in the event of an emergency (e.g. a fire engine might be used to pump water to the reactor core during an emergency.).

    c. Your new unit will likely have a digital control room. Industry plant operating history and thus experience is limited. Your computerized procedures must:

        i. Incorporate best practice for use of human performance tools (HU Tools) with computerized procedures by operators (e.g. self-check, place keeping, independent verification, etc.). See the suite of HU tools specified in the functional section for the NPI function.

        ii. Develop user-friendly, paper-based backup procedures that operators can readily use in the event of a loss-of-computer-service plant event. The use of these backup procedures should be practiced during operator simulator training.

        iii. Include operations and/or I&C recovery guidance for DCS restart in your scope of required procedures.

    d. Define how your HU tools should be incorporated into procedures (e.g. place keeping or independent verification). This should be defined by your procedures' writers guide.

    e. Require that procedure bases documents be provided for all alarm response guidance, and plant abnormal and emergency operating procedures (to include severe accident and excess core damage procedures), and technical specifications. Bases documents are essential to high-quality training and operator understanding. Without bases documents, your operators may know what to do, but not why they are doing it – a critical distinction when faced with new or unique situations.

If your vendor does not have procedure bases documents, engage the applicable PWR, BWR or CANDU owners' groups to help create these for your plant from generic guidance. (Reminder: There is no corresponding VVER owner's group, demand procedure bases documents from your EPC contractor.)

12. Operator staffing and training

    See Section D regarding your journey to operational readiness. The critical path for operational readiness should flow though the staffing and qualification of your MCR operators. Early and robust support for all elements of MCR operator training is essential to ensure vital operator support for the commencement of HFT.

    All training materials should be provided in the plant operating language. Where a language difference exists, it is imperative to get early delivery of procedures, bases documents and training materials. Early delivery will help provide time to correct the document content corruption that comes with translation.

13. Transfer of plant knowledge and skills to the owner

    Except in dramatic first of a kind (FOAK) plant design and construction efforts, your contract will likely specify a reference plant. This reference plant is important to the preparation of personnel to operate the new plant. This is especially true for new plant, new company and new country entrants. Contract provisions should specify what and how the following types of activities will occur utilizing the reference plant:

    a. Classroom training
    b. Simulator training
    c. On-the-job (OJT) training
    d. Job shadowing
    e. Bench marking
    f. Observations of both normal and outage activities
    g. Access to corrective action program data, root cause reports, etc.
    h. Language training as required

    Personnel learning is accelerated by participation in commissioning and power ascension testing activities such as HFT. Your contract should clearly specify the intent to second personnel from all desired employee core functions to conduct MCR activities, plant field operations, chemistry sampling, etc. during commissioning and power ascension testing. Specify that owner personnel who are trained and qualified will not only be seconded, but will be expected to make decisions and take plant actions (i.e. manipulate plant components). Owner personnel in training will be expected to do so under oversight of qualified personnel. Owner personnel should not be relegated to watching someone else operate their plant.

> Caution: Your construction contractor is most certainly a different organisation than the reference plant organisation. Establishing a relationship with the reference plant operating organisation and confirming expectations with this organisation's leadership will be critical to the quality delivery of the support activities you desire. Take steps early to form a relationship and develop a formal Memorandum of Understanding (MOU) with your reference plant operating organisation as part of the contract development process.

14. Critical plant/program support facilities

    a. Plant simulator in support of plant operator training.

       Ideally, plan to have at least one fully capable and functional ANSI licensed simulator for each unit planned for construction and operation. The demands of training for both initial license training and testing, continuing training, simulator scenario development and validations, simulator certification activity, simulator maintenance and simulator upgrades will create conflicting demands that can threaten the timely readiness of your operators and delay planned startup and operation. (Note: Plant sites with more than four units of common design may benefit from operational leverage and require less than the 1:1 rule for simulator per unit.)

       Schedule simulator construction and readiness early to support operational critical path to HFT (i.e. the training and qualification of your MCR operators). Based on initial plant design, the simulator and supporting procedures must be capable early of exercising operators in normal plant operation and challenging them with plant equipment failures (covered by alarm response procedures and abnormal operating procedures (AOP), emergency events (covered by EOP procedures), and severe accident conditions (covered by SAMG procedures). Expect and plan for simulator revisions that will be required to match the built plant including all plant design changes implemented.

       Contingency plans for even more additional simulator capability should be contemplated. This is particularly important for sites with more than two units where the demand for and complexity of simulator needs can create unforeseeable peaks and potential delays.

       See the industry success story in Appendix 5.

    b. Maintenance support facilities

       i. Mock-up training facilities will support a high-quality initial and continuing maintenance training program. The timing of the construction and equipping of these facilities is critical to efforts to train and qualify maintenance personnel early. Typical mock-up training facilities include refuelling machine, steam generator, reactor head, reactor coolant pump, large electrical equipment and some I&C training loop simulators.

       ii. Establish designated training areas and support equipment in maintenance staff, vendor and constructor workshops.

       iii. Locate maintenance shops convenient to efficient plant access.

iv. Consider accommodation for the installation of maintenance works areas within the plant-controlled areas. Such accommodation should include relevant tool and spare parts storage and staging.

c. An outage control centre (OCC) in the plant:

Refuel outages are your future high cost, no revenue events. Shorten outage durations to enhance worker productivity, reduce cost, and improve all aspects of safety performance by doing the following:

i. Designate, build and equip a high-quality OCC.

ii. Equip the OCC with high-quality audio and visual communication and display equipment.

iii. Link plant cameras in outage critical areas to the OCC communication suite.

iv. Enhance the work environment of containment with the allowances previously cited in step 7b.

Opportunity: The OCC facility and its unique communication and coordination features can be used near term in your efforts to coordinate the transition from construction processes, programs and behaviours to operations. Similarly, the OCC can serve as a command centre to coordinate plant fuel load, startup and testing activities. As a further benefit, such use will exercise this capability and help prepare the organisation for future outage evolutions.

d. An outage management and support building within the security protected area.

Once again, refuel outages are your future's high cost, no revenue events. Shorten outage durations, improve safety, enhance worker productivity, reduce cost, and improve all aspects of safety performance by doing the following:

i. Accommodate station management personnel dedicated to ongoing outage scheduling, planning and preparation activities.

ii. Accommodate contract management staff mobilizing for pre-outage preparation, outage execution and wrap-up.

iii. Accommodate outage support maintenance staff (including in-processing facilities and services).

iv. Provide expanded outage maintenance support activity areas for both hot and cold maintenance.

Any outage management support facilities should allow for effective and efficient communication with the OCC.

e. Seismically and environmentally qualified on-site emergency facilities.

One of the lessons learned from Fukushima and the Kashiwazaki-Kariwa events was the need to have an on-site emergency facility that could withstand design earthquakes and contaminated air. The Chuetsu-Oki earthquake in 2007 prompted Tokyo Electric Power Company to build seismically and environmentally qualified emergency operating building on their nuclear power plant sites. This building at Fukushima Daiichi made a significant positive impact on the accident support effort during and after the earthquake and tsunami in 2011.

15. Stipulate a formal plan for a post-construction and commissioning design freeze.

    At some point post-construction and the first full round of commission testing, you will have a need to free the installation of plant design changes required for safe plant startup and operation. This plant design freeze will create a period of time for the constructor to collect and store plant data, and complete plant drawing changes. For the operator, this period of time allows for associated design change procedure revisions and follow-on training lesson plan upgrades. Subsequent operator and technical training, often referred to as delta training, must then be conducted for all plant operators prior to plant startup and operation. In principle, this period of time allows everyone to be familiar with the as-built plant.

    Depending on the performance of plant systems and components during commissioning testing, a second design freeze may be required to accommodate the additional scope of plant changes.

16. Efficient management of plant area access doors.

    New build projects frequently cite inefficiencies and frustrations while managing plant and area access doors during different project phases. Typically, construction groups use a set of door locks and keys which must be replaced by commissioning staff when an area handover takes place. Similarly commissioning often change locks as part of the handover to operations. This practice of using conventional, mechanical key and lock configurations results in significant additional work, worker ingress/egress delays, and frustrations during required project phase transitions.

    Consider the deployment of electro-mechanical locks for sensitive plant area door controls. It is now possible to fit one unique locking barrel in such doors and operate these via a secure Bluetooth key which can be re-programmed as needed for use by different work groups. An electronic control system results in fewer keys, fewer physical lock changes, and provides a much simpler and efficient lock transition. The system is in use successfully at one new nuclear project and is endorsed for use at a second. The system contains many additional benefits, ranging from an option to link the keys with personal work packages and a fail-safe disabling of function if accidentally removed from the nuclear site (e.g. Abloy Locks – Cliq2 System).

Operational Considerations during Construction:

You will eventually operate what you allow your vendor to build. The quality of plant system and component construction and installation will effect near and long-term plant performance. As the owner, invest money in the creation of a strong construction oversight capability. The employment of qualified and experienced construction oversight personnel with your interests in plant quality in mind can dramatically improve future plant reliability and the cost of plant operation.

Effective project construction oversight should include:

1. Develop construction oversight capability and capacity as follows:

    a. Staff the organisation with personnel who have nuclear plant construction and/or operational experience. Consider the use of an experienced third-party vendor to provide qualified and experienced QA and QC personnel and expertise.

    b. Train these personnel to your standards and expectations for:

        i. Quality plant construction

        ii. Construction support process and programs implementation and execution

        iii. Construction personnel behaviours

        iv. Construction management behaviours

        Use WANO and IAEA new unit resources to share industry lessons learned.

    c. Encourage these personnel to identify, document and report all field installation deficiencies, especially for safety-related and single point vulnerability systems. Provide them cameras to help capture deficiencies.

    d. Be sure to include factory QA and QC inspection activities for all manufacturing efforts completed on your behalf. This is especially important during large-scale prefabrication efforts. There are industry experiences of costly failures due to factory prefabrication mistakes that could have been prevented with quality QA and QC inspections.

    e. Create and implement a supporting corrective action process for construction deficiencies. Manage these issues to closure, including follow-up problem resolution verification.

    f. Empower oversight personnel with a protocol and expectation to exercise their authority to stop work and/or subsequently issue formal stop work orders (SWOs) when and where behaviours occur that adversely affect safety or quality. Examples where SWOs would be appropriately deployed include violation of FME requirements, improper separation of stainless steel and carbon steel work assembly areas, and poor industrial safety practices.

    Use the capability above to find, capture and help resolve the following problem types during your construction effort.

2. Quality control for containment building structures

    The containment building structure is typically designed to support 100 years of plant operation. Non-compliance with code requirements for the manufacturing and placement of containment concrete can lead to cracking and defects that pose risks during plant power operation. Improper placement of concrete has resulted in voids in the structure, necessitating costly repairs.

3. Quality control for safety-related equipment

   Vigilance is required to ensure genuine safety-related equipment is manufactured, tested and delivered for installation. Several incidents related to counterfeit, fraudulent and suspect items, such as safety-related cables, mounting bolts, fastening bolts, and data cables have caused major delays at some nuclear power plants. In addition, the installation of inferior primary system piping and components can lead to significant outage periods resulting in lost revenue, high repair costs, and a large accumulation of radiation dose.

   A robust program for the prevention of counterfeit, fraudulent and suspect items (CFSI) should be developed and implemented. Bench marking of such programs is recommended.

4. Configuration management

   Careful control of plant modifications, especially for safety-related systems, must be accomplished, including the incorporation of updates to plant design documents. These modifications must be performed using a well-defined process or program.

5. Foreign Material Exclusion (FME)

   Designate your FME expertise and get engaged in construction FME prevention efforts early.

   Even in the earliest stages of construction, FME controls of various types should be in place to prevent foreign material introduction to plant components. Professionally designed FME covers and caps (especially for safety-related equipment) can prevent equipment wear, prevent damage, and extend component life. Uncovered panels, pipe openings and exposed windings are not acceptable, as are ad hoc materials such as duct tape, plastic sheeting, etc.

   Plant cleanliness throughout construction should be constantly monitored and maintained. General housekeeping practices should be employed, to include providing bright lighting throughout the plant, controlling potential sources of dust generation, clearly designating paths for foot traffic, and properly filtering ventilation.

   A quality FME program must focus on prevention, not recovery. Industry experience has proven that full reliance on inspection and retrieval practices and/or final system flushes is ineffective when attempting to fully protect plant system and components. In evidence of this, over 60% of all new build projects have experienced FME-induced fuel failures during the first cycle of operation.

   As previously noted in Section F of the roadmap, many FME related SRAFIs have been identified by WANO during PSURs.35

6. Standards of construction quality (especially for safety-related systems)

   a. System piping supports and layout:

      Piping supports should be properly installed in the specified design locations. Missing or inadequate piping supports should be identified and corrected.

      Ventilation dampers should be properly installed in the specified design locations.

[36] WANO PL2012-08 Excellence in Foreign Material Exclusion

System piping in touch with adjacent piping poses a risk of damage due to excessive abrasion, increased stress due to differential thermal expansion or motion, or corrosion due to the interaction of dissimilar metals.

b. System cable installation, cable support and layout of plant cabling

   Deficiencies include excessive numbers of cables running in one cable tray, cables placed on the sharp edges of a tray, and inadequate support for cable tray weight loading.

   The proper location of electric cabling and instrumentation wiring for multi-train systems should allow for physical separation. This helps prevent common faults from removing 100% of a specific plant capability. Identify and correct circumstances where such cable and wiring runs are inappropriately placed in common cable trays or wiring runs.

c. Permanent plant equipment hardware should be installed in accordance with the design documents. This includes removal of shipping and storage packaging, and temporary supports or temporary modifications associated with testing. It also includes proper installation of bolting, gaskets, operating devices, etc.

d. Permanent plant system operating equipment should not be installed in contact with or with very small clearances to other plant equipment such as guardrails, stairs, ladders, unintentional supports, tanks, etc.

e. Electrical or piping systems passing through concrete penetrations should be free of direct contact with concrete surfaces and have adequate clearance to avoid interaction during thermal expansion or seismic events.

7. Protection of installed systems and components from adjacent construction activities (especially safety-related systems).

   a. Many scaffolds are used during construction. Such scaffolds can be improperly erected in direct contact with equipment and associated piping and cabling. Scaffold contact during subsequent component operation can damage equipment. Weight loading on components can cause deformation and damage. Additionally, scaffold impacts incurred during installation and removal can cause damage to components such as sensors and sensing lines.

   b. Similarly, guards, covers, shields and platforms should be installed to prevent touching of and damage to sensing lines, insulation and other components from workers stepping, walking and standing on them.

   c. Protection from environmental contaminants:

      i. The construction environment can be a very dirty one. Dirt, dust and moisture pose a threat to electric and instrumentation panels and components. Require the use of temporary plastic wrap and bags to encapsulate panels and sensitive instrumentation before and after installation while not in use.

      ii. Corrosive chemicals such as halogenated adhesives and marking materials used during construction activities can promote stress corrosion cracking of stainless steel For example: 304 stainless steel susceptible to stress corrosion cracking used in liner plates throughout the plant including liners for the spent fuel pool and plant water storage tanks. At one new plant, significant cracking and damage of the liners occurred because cleanliness was not maintained in a highly corrosive environment. If discovery of such issues occurs during plant operation, significant plant outage time tied to issue resolution and/or component repair can be incurred.

iii. High salinity environments threaten to incite accelerated rates of corrosion. As applicable, galvanic and cathodic protection systems must be installed and maintained.

iv. Adverse weather conditions can threaten long-term equipment integrity in several ways. Preventive steps may require the installation of lightening arrestor systems needed for the protective grounding of electrical systems and components. In addition, high voltage electric and switchyard equipment should be protected from damage during high wind conditions.

8. Safety-related system pipe flushing

   Flushing activities that are incomplete or inappropriate can cause equipment damage, malfunction, and in some cases foreign material intrusion into nuclear fuel assemblies.

9. Early fire prevention

   Both the project's success and the owner's asset need to be protected during the construction phase. The threat of fire initiation during construction is high due to multiple factors, including significant amounts of combustible materials and a preponderance of welding activities. Accordingly:

   a. Fire protection system installation, commissioning and placement into service should be scheduled to support fire-related risk reduction. To protect your new asset, improve fire suppression availability by installing and commissioning fire systems section by section.

   b. Limit the quantity of combustible materials in the plant at all times. Reduce the introduction and accelerate the removal of combustible materials from the plant. Consider prohibiting the use of wooden materials in the plant, including the use of non-combustible scaffold planking. Plan to routinely survey combustible material build-up in the plant and take corrective action.

   c. Fire response and suppression capability should be rigorously exercised, assessed and constantly verified and/or enhanced.

   Such planning and effort will also please your insurer.

10. Finally, plan to be present (and active as required) in regular vendor and/or its subcontractor's work planning, scheduling and issue resolution meetings. You should be suspicious of any contractor reluctant or unwilling to allow open access to such meetings.

Operational Considerations during Commissioning:

The start of commissioning begins the process of breathing life into the plant. The nature of plant and personnel activities starts to feel like plant operations. Depending on your level of readiness, the commissioning period provides you three challenges or opportunities:

- Collect, disseminate and begin to use plant data and information. Use this to monitor, trend, analyse and address plant problems for systems in testing and in service.
- Implement and execute applicable operational processes, programs, procedures and protocols (e.g. log keeping, out of service/tagging, fire impairment control for in-service systems, etc.).
- Introduce and begin to reinforce operational standards and expectations for plant personnel behaviours (e.g. MCR professional decorum, plant monitoring standards both inside the MCR and in the field).

Think of the start of commissioning testing as that point at which the organisation begins to think like, make decisions like, and behave like an operator. In general, the sooner the better.

1. Plant data and information

   Significant amounts of plant component and system operating information is generated during the commissioning phase. This information will be the baseline performance information for safety-related equipment, as well as provide an early identification of any design or equipment deficiencies.

2. Operating procedures

   Some testing will necessitate the use of plant component and system operating procedures. This creates an opportunity to use and validate (and revise when necessary) operating and/or surveillance test procedures. Operational standards for procedure use and adherence (an HU tool) and place keeping (another HU tool) should be established and reinforced to take advantage of this period. These behaviours, when conducted properly, will improve the pace of procedural improvement.

   The data collected during commissioning tests serves as a confirmation of performance to design specification and must often be incorporated into operating and surveillance test procedures to be used later during plant operation.

3. Safety-related equipment performance monitoring

   Plan to monitor and trend key equipment performance parameters during plant commissioning testing. This data should be captured in appropriate equipment reliability program performance monitoring databases.

4. Effective analysis of plant system and component failures

   a. Investigation and analysis competency

      Analysing equipment reliability issues and component failures is difficult technical work. Experts are not easy to find – especially within the ranks of a construction firm. At a minimum, ensure that competent professionals with the requisite skills are available to serve your project. Strongly consider contracting with a competent third party to either conduct or review the products of all system and component failure analysis that is to be conducted for your project.

b. Failure causal analysis

Equipment will fail, components will break, and systems will operate poorly. This is to be expected. In pursuit of schedule and cost, your constructor will tend to expeditiously take action to correct plant system and component symptoms, not causes. However, neglecting to understand the fundamental cause of a problem (design, operational, installation, materials, etc.) may simply postpone recurrence until plant operation when the system response can adversely impact nuclear safety. Therefore, it is paramount to understand why deficiencies exist and to address the underlying causes. .

As the owner responsible for operation, you have an obligation and a business need for safe and reliable plant operation. Discovering the cause of equipment failure is the key to proper and effective long-term corrective action. A causal evaluation, commensurate with the safety significance of the failure should be performed at the same level as defined in your plant operations corrective action program. Hold your constructor accountable to identify, explain and fix the underlying cause of equipment deficiencies.

Finally, consider the commissioning phase of the project to be an opportunity to develop your organisation's causal analysis capability. This is a vital and valuable skill for your operating organisation to develop and maintain. Additionally, consider the use of independent third parties to perform these evaluations in parallel or after your station review to ascertain the ability of your personnel to reach the same conclusions.

c. Extent of condition analysis

An important part of a causal evaluation is the determination of extent of condition. There is ample new construction industry experience where issues reoccur during subsequent unit construction on the same site or elsewhere. This highlights not only the importance of understanding the cause of a condition, but further determining where else the condition may occur.

Equipment failures experienced during the commissioning stage often have causes that can or have manifested in other plant activities, components or systems. Thus, similar problems or failure mechanisms can arise elsewhere. Again, the constructor will be far more likely to address the problem in front of them and move on. An unqualified welder, inferior FME barriers, contaminated reagents, and faulty electrical test equipment are just a few examples of causes for material and equipment failures that can likely show up elsewhere. As the owner, very deliberately ask the extent of condition question: "Now that we know the cause, where else might this be a problem?" Be sure to satisfy yourself that the answer to your question makes sense and is technically sound.

5. Equipment performance during commissioning tests

   a. Commissioning oversight personnel must be trained to identify problems in the field as well as review and properly analyse component and system test results. You, the operator, should establish inspection standards and train and qualify personnel to these inspection standards. Take advantage of every opportunity to engage operating organisation technical personnel in plant equipment surveillance, testing and problem analysis.

   b. The design of plant and system commissioning tests must ensure plant system and component capability as required by your plant's technical specifications for operation.

   c. The outcome of commissioning tests must ensure that plant systems and components can meet the requirements of your plant's technical specifications for operation. Commissioning test results should be evaluated with consideration for future plant system and component operability during plant operating conditions.

6. Foreign material

   Foreign material is generated in great quantities during construction. This material can and will find its way into plant components and systems. Such foreign material will cause component damage and impair system performance. Most critically, foreign material is a key contributor to nuclear fuel failures. By way of example, over 60% of new units started up between the years of 2013 and 2016 experienced fuel failures in their first operating cycle because of foreign material intrusion.

   A program for FME control and management is required. This program should define standards, establish robust barriers, and implement formal controls to minimize the threat of intrusion of unwanted material that can impact equipment and system performance. While a construction period FME program may differ from an operating FME program, the philosophy and fundamental elements should be similar. For example, a philosophy of prevention versus recovery should be defined and embraced (i.e. flushing should be a cleanliness verification process instead of a cleaning process, especially during later commissioning activities). Formal plant equipment barriers should be defined, purchased, stocked and religiously employed throughout the plant. Make FME covers readily available to construction personnel.

   FME is another candidate for program bench mark or purchase from strong operating plants.

7. Requalification or quality control of replacement parts

   It is also important to verify that proper quality controls are in place to ensure genuine components are being used as replacement parts or spares.

8. Equipment labelling

   Quality, rule-based procedures depend on detailed and accurate plant component labelling. The process and standards for component labelling (both temporary and long term) should be well defined and incorporated into procedures and checkoff lists for plant system turnover for blocking (TOBO) and plant system turnover for testing and operation (TOTO).

9. Equipment and system protection

   Systems need to be protected from the balance of remaining construction activities. As an example, scaffold construction and removal in support of welding, painting, tagging and cleaning activities elsewhere pose a threat to systems being ready for operation.

   Consider the development and implementation of a program for protecting systems and associated operator pathways. The installation and control of high-quality, professional barriers can prevent many problems.

   Where possible, limit all but required personnel to plant systems and areas by programming door access security passes. The intention is to prevent area access and inadvertent equipment damage by unauthorised staff.

   Additionally, for multi-unit facility construction, consider barriers and access to the soon to be operating plant from the other plant(s) under construction and/or commissioning.

10. Equipment preservation:

For plant components that are ready for operation (i.e. satisfactorily tested) but are not required for operation until later, make provisions for equipment layup for the time frame between commissioning and the commencement of operations. Requirements for the development and execution of a formal preservation and layup program should be specified. The chemistry department should develop, implement and lead the execution of equipment preservation program for your plant.

For plant components in operation (e.g. cooling systems, HVAC systems), make provision for a robust equipment monitoring program and an intrusive preventative maintenance program for the time frame between commissioning and the commencement of operations. These programs should have a foundational basis and require active equipment and component maintenance consistent with that for a high-quality, online, preventive maintenance program. System engineering should develop, implement and lead execution of the equipment monitoring program. Maintenance should do the same for the plant equipment predictive and preventive maintenance program, to include the scheduling, planning and conduct of equipment maintenance activities.

During commissioning, any system that is already in service should be properly separated from the construction area to ensure its protection and to isolate construction workers from energized and running equipment.

Appendix 2: Operating Model Essentials

Recommended List of Functions (in Alphabetical Order)

The following list of 39 functions are typical of a nuclear plant operating organisation. The list includes all typically required corporate, support and core operating functions. Each function presented includes a basic description of the primary areas of responsibility.

1. Administration (Administrative Support) - Primary responsibilities include secretarial and logistic support for managers, directors and executives.

2. Chemistry - Primary responsibilities include the monitoring and management of plant primary and secondary system chemistry. Responsibilities also include the management of chemistry support facilities (e.g. water plant, chlorination facilities, etc.).

3. Commissioning Oversight - Primary responsibilities include the governance, oversight and support for plant CFT, HFT and startup testing. This is a temporary organisation that exists through the attainment of plant commercial operation.

4. Communications - Primary responsibilities include internal and external communications. Responsibilities also include non-operational stakeholder management and public outreach efforts.

5. Decommissioning - Primary responsibilities include the planning and preparation for end-of-life plant decommissioning. Early responsibility includes creating provisions for funding future plant decommissioning efforts.

6. Document Control and Records Management - Primary responsibilities include the management of all plant documents to include procedures, prints, drawings, letters, etc. Management includes the creation, processing and retention of all plant documents.

7. Emergency Preparedness (EP) - Primary responsibilities include on-site and off-site support for nuclear emergency plan development and execution. It includes business continuity planning and management.

8. Engineering - Primary responsibilities include the management and oversight of the plant design, system operation, technical program execution, and the specification of plant components in support of procurement.

9. Environmental Management - Primary responsibilities include the governance, oversight and execution of plant environmental programs for the management of plant airborne, liquid and thermal releases.

10. Export Controls - Primary responsibilities include the governance and oversight of plant technical information sharing with all stakeholders.

11. Facilities Management/General Services - Primary responsibilities include the upkeep of non-nuclear facilities and the provision of a wide range of organisational support services to include transportation, accommodations, food services, etc.

12. Finance - Primary responsibilities include budgeting, cost control, revenue management and insurance activities in support of plant operation.

13. Fire Protection (FP) - Primary responsibilities include the management of all programs and activities related to plant fire prevention and fire response capability.

14. Fuels - Primary responsibilities include the complete management of the fuel cycle. It does not include reactor engineering. While the fuels function provides critical support to plant operation, functional reporting to the operating organisation varies widely from one industry organisation to another.

15. Health and Safety (H&S) - Primary responsibilities include the governance, oversight and support of plant industrial safety standards and programs.

16. Human Resources (HR) - Primary responsibilities includes the governance and oversight of employee policy and supporting programs. Responsibilities also include the management of processes for talent acquisition, organisational capacity building, non-nuclear personnel training and development, and career management.

17. Information Technology (IT) - Primary responsibilities include the governance, oversight and support of all information technology hardware and software. This does not include plant digital equipment maintained by maintenance instrumentation and controls personnel.

18. Integrated Management System - Primary responsibilities include the development, implementation and management of the organisation's integrated management system. This small function exists in organisations that create and maintain a formal, operating model as described in Section C of the roadmap.

19. Internal Audit (IA) - Primary responsibilities include the oversight and assessment of the organisation's commercial and financial decision-making and associated transactions.

20. Legal - Primary responsibilities include management of all organisational legal matters to include corporate governance. Responsibility also includes management of the employee concerns program.

21. Licensing and Regulatory Affairs - Primary responsibilities include the preparation, submission and subsequent management of a plant's construction and operating licences and permits. Responsibility also includes nuclear regulator relationship management.

22. Maintenance - Primary responsibility is the preventive and corrective care of nuclear plant facility and equipment. The scope of these maintenance efforts includes the disciplines of electrical, instrument and control, mechanical, program and contract management. As discussed in the roadmap, the responsibility for maintenance planning early in plant life resides with the work management function.

23. Management (senior and executive level) – The body of upper management positions within the organisation that have responsibility for two or more functions (e.g. plant manager). Responsibilities, in addition to day-to-day direction for plant and organisational matters, include corporate strategy development.

24. Nuclear Oversight (NO) - Primary responsibilities include the daily oversight of nuclear plant operation and the facilitation of independent external oversight services.

25. Nuclear Performance Improvement (NPI) - Primary responsibilities include the governance, oversight and support of processes and programs related to corrective action (CAP), operating experience (OE), performance assessment, bench marking and human performance (HU). Responsibility also includes all efforts planned and executed with the support of the HR and OR functions to achieve and sustain a healthy nuclear safety culture.

26. Nuclear Risk Management - Primary responsibilities include the determination of the plant's design safety analysis, oversight of plant operation, and the maintenance of design margins.

27. Operations - Primary responsibilities include the safe startup, operation and shutdown of the nuclear plant and critical support equipment. The daily effort includes decision-making and plant component manipulation in accordance with plant procedures and within the limitations specified by plant technical specifications. The function is responsible for the staffing and qualification of plant operators. Management efforts include electrical generation planning.

28. Organisational Effectiveness (OR) - Primary responsibilities include the assessment and analysis of both leadership and organisational behaviours and the resultant cultural impact. When required, includes language proficiency programs.

29. Plant Projects - Primary responsibilities include the budgeting, scheduling, planning, preparation and execution of large plant component replacements and major system upgrades and modifications.

30. Procurement & Supply Chain - Primary responsibilities include commercial contracting, the sourcing and acquisition of plant parts, consumables and services, and the warehousing of plant spares.

31. Program Management - Primary responsibilities <u>initially</u> include the scheduling, planning, oversight and reporting of all operational readiness activities. Over time, this function evolves to include support for corporate strategy development, risk management and business planning (to include industry bench marking). Long-term responsibilities also include operational performance monitoring and the management of key performance indicators.

32. Quality Assurance (QA) - Primary responsibilities include the oversight and assessment of plant documents, records and activities to verify compliance with prescribed standards of quality.

33. Radioactive Waste Management - Primary responsibilities include management of liquid and solid materials either contaminated or activated at low, medium or high levels.

34. Radiological Protection (RP) - Primary responsibilities include the monitoring, assessment and mitigation of all plant sources of radiation, and the control of irradiated and/or contaminated materials. Responsibilities also include the monitoring, prevention and management of employee radiation dose.

35. Reactor Engineering (RE) - Primary responsibilities include monitoring the operation of the reactor core and the performance of its reactor fuel.

36. Safeguards - Primary responsibilities include the oversight and management of special nuclear plant materials.

37. Security - Primary responsibilities include the physical protection of the nuclear site and its plants from all external and internal threats. Additional responsibilities include cybersecurity.

38. Training - Primary responsibilities include the conduct of core technical training for personnel in the core disciplines of operations, maintenance, chemistry, radiation protection and engineering (to include reactor engineering). Responsibilities include classroom and simulator instruction, testing and records management. The responsibility in operations includes support for licensure.

39. Work Management (WM) - Primary responsibilities include the management and/or facilitation of organisational efforts for online and outage (forced and refuel) scheduling, planning, preparation and execution. As discussed in the roadmap, the responsibility for maintenance task planning early in plant life resides with the work management function.

Of the above 39 functions, six are designated as core operating functions. The six core operating functions are chemistry, engineering (including reactor engineering), maintenance, operations and radiological protection. Core operating functions distinguish themselves from other functions as follows:

- The function has defined principles and standards of conduct based on industry experience.
- Functional personnel must demonstrate requisite knowledge, skills and behaviours (i.e. fundamentals).
- Functional personnel have the highest level of direct impact on day-to-day operational decision-making and plant manipulation.
- The functions are supported by rigorous initial and continuing training programs. The supporting training programs are based on a formal systematic approach.
- The functions are the focus of both internal organisational performance oversight and external assessment and evaluation (e.g. WANO).

Subject to effective leadership, strength in plant performance is directly dependent on the capability and capacity of personnel in these six functions.

Appendix 2: Operating Model Essentials

Recommended List of Processes

1. Plant Operation
2. Work Management
3. Configuration Management
4. Equipment Reliability
5. Loss Prevention
6. Materials & Services
7. Nuclear Fuels
8. Support –Various
9. Talent Management
10. Performance Improvement
11. Management Oversight
12. Independent Oversight

Note: The above list of processes is not recommended as the basis for organisational design. Some utilities do use this process structure as a basis for cost structuring. By way of illustration, most if not all plants within the United Sates use a consistent structure of cost codes predicated on the process model above. They do this in accordance with guidelines provided by the Electric Utilities Cost Group (EUCG). Aligning to this guidance allows for comparative cost bench marking and analysis across plants and companies while protecting corporate proprietary information and intellectual property.

See www.eucg.com

Appendix 2: Operating Model Essentials

Recommended List of Programs

The list of programs that follows is a potential scope of programs for a new nuclear operation. Some of these programs are technology dependent and are indicated as such. New nuclear members should formally review these programs for applicability. Programs deemed not required should have a documented basis for such decisions. The documented results of such a review, and the justification for any program elimination, should be independently reviewed and approved.

What criteria distinguishes a program?

A program is a planned, coordinated group of activities, processes or applicable process steps, governed by procedure, developed to accomplish a clear safety objective or purpose. Programs specify organisational performance objectives and criteria. They cite applicable regulatory requirements from any and all sources. Programs detail what work is to be done, by whom, at what periodicity, and by what means or resource. Programs are implemented by procedure.

Programs are typically characterized by the following criteria:

a. Require a designated expert: Programs are technically complex with many requirements and specific technical expertise. An expert is needed to understand these requirements, oversee program implementation, and analyse the results. In addition, program experts participate in related industry groups to remain aware of evolving program requirements, implementation methods and related technologies.

b. Exist for the life of the plant: Programs are required by a reference document or requirement that exists for the life of the power plant (e.g. regulations, technical specifications, codes and standards, etc.) and support safe and reliable plant operations. Reference documents include, but are not restricted to, regulations, technical specifications, the FSAR, industry codes and standards, standard nuclear industry practice, or expert judgment.

c. Collect data at regular intervals: Program data collection activities are repeated at regular intervals at a frequency defined either by time (e.g. monthly or quarterly) or by event (e.g. maintenance or refuelling outage). Technical tooling is often required for data collection. Administrative and software tools support data capture and retention.

d. Provide data continuity and performance trend monitoring: Data is collected each performance cycle. Data is compared to applicable technical requirements to assess performance and determine compliance. Data is compared to the previous cycle and is used as an input into the next data collection cycle. Data collection, comparison and trending, as required, is used to determine performance degradation over time and allows for actions to prevent unacceptable performance before it occurs.

e. Often supported by technical training and/or qualification/external certification.

f. Subject to periodic regulatory review.

In many circumstances, the development of industry programs has originated in response to adverse performance experiences that demanded more effective and focused management.

Are all programs equal in significance?

As previously discussed in the manual, your regulator will expect routine access to and the right to scrutinize all aspects of plant operation, including program execution. This is appropriate regulatory behaviour and needs to be respected. As a rule, nuclear regulators and their regulation will focus on programs critical to reactor safety. While all of the programs listed are important, some will be of greater significance to reactor safety. Programs should be designated by level of significance. The three recommended designations are:

- Regulatory: a program designed to comply with the requirements of the nuclear regulator.
- Technical: a program designed to comply with the requirements of other regulatory bodies (e.g. OSHA).
- Administrative: a program designed to comply with a predetermined business objective(s) and/or criteria.

These three categories are listed in the order of significance. The intent of charactering programs by these designations is to help limit the scope of plant operating content subject to potential regulatory action.

Recommendation:

New nuclear members should formally review this program list for applicability. Review steps should include:

1. Collection or determination of local regulatory requirements.
2. Determination of desired performance standards.
3. Program list review and selection.
4. Program designation – regulatory, technical or administrative.
5. Formal documentation of determination decisions and justification.*
6. Schedule and plan for program development, implementation and execution.

*Note: Programs deemed not required should have a documented basis for such decision. The documented results of such a review, and the justification for any program elimination, should be independently reviewed and approved.

Operations List of Potential Programs

#	Program (Provided in alphabetical order)	Type	Tech.	Function	Definition
1	Accident Management	R		Nuclear Risk Assessment	A program covering the preparatory measures and guidelines that are necessary for dealing with a DBA and beyond DBAs, including Severe Accidents, including events involving the storage of irradiated nuclear fuel.
2	Ageing Management	T		Engineering	A program for managing the ageing for nuclear power plants to assure the availability of required safety functions throughout the service life of the plant, with account taken of changes that occur with time and use, including addressing both the physical ageing and obsolescence of structures, systems and components (SSCs) that may result in degradation of their performance characteristics or in comparison with current knowledge, standards and regulations, and technology.
3	Air Operated Valve	T		Engineering	A program encompassing the activities associated with design verification, evaluation, testing, preventive maintenance, and surveillance of air-operated valves in order to provide assurance that AOVs with safety significance, importance to plant reliability, and/or thermal performance are capable of performing their intended functions.
4	Benchmarking	A		NPI	A program of systematic industry surveillance, data collection, performance comparison, and evaluation to include the formal collection and consideration of lessons learned and best practice with the intent to improve plant safety, effectiveness, efficiency, and or cost
5	Boric Acid Corrosion Control	T	PWR	Engineering	A program to assure that leakage from systems borated for the purpose of reactivity control is identified, evaluated, trended, and repaired to prevent degradation of pressure boundary or other station sturctures, systems, or components (SSCs).
6	Chemical Control	T		Chemistry	A program for assuring compliance with safety, environmental, and regulator policies for the management and use of chemicals, including an approval process for introduction and use of chemicals, maintenance of a comprehensive chemical inventory, management of Material Safety Data Sheets (MSDS), on-site chemical management, and proper waste disposal.

#	Program (Provided in alphabetical order)	Type	Tech.	Function	Definition
7	Chemistry Quality Assurance Program (CYNISP-201)	T		Chemistry	A process for effectively implementing a quality assurance program to ensure there is a high degree of confidence in the analytical results of key parameters at a nuclear power station.
8	Component Health Program (CHIP)	T		Engineering / Maintenance	A program to ensure long-term equipment reliability of station components tincluding life cycle management of the assets by setting priorities based on component importance, performance, and impact on the station, as well as by ensuring the component engineers/specialists receive appropriate support from other organizations. Reference AP-913, Equipment Reliability Process
9	Containment Leak Rate Testing	R		Engineering	A program for identifying and quantifying leakage through the primary containment and containment isolation components in order to demonstrate compliance with Regulatory requirements for containment leakage and the technical specifications.
10	Control Room Envelope Habitability	R		Engineering	A program to assure that the Control Room Envelop, which consists of the physical barriers (floors, ceilings, walls, doors, ducts, dampers, etc.) that separate it from other plant areas and the main control room heating, air-conditioning, and ventilation systems, including the control room emergency filter system, are functioning to provide a habitable environment for operators under normal and accident conditions, including hazardous chemical and smoke infiltration, to protect the health and safety of the public.
11	Corrective Action Program (CAP)	R		NPI	A program of systematic problem identification, documentation, and review followed by evaluation and remedial actions where warranted.
12	Cyber Security	T		Security / IT	A program for assurance that digital computer systems, communication systems, and networks associated with safety-related and important-to safety functions, security functions, emergency preparedness functions including offsite communications, and support systems and equipment which, if compromised, would adversely impact safety, security, or emergency preparedness functions are adequately protected against cyber security attacks up to and including the Design Basis Threat (DBT) in accordance with regulatory requirements by implementing and documenting the "baseline" cyber security controls and implementing and documenting a cyber security program to maintain the established cyber security controls through a comprehensive life cycle approach.

#	Program (Provided in alphabetical order)	Type	Tech.	Function	Definition
13	Emergency Preparedness (EP)	R		Emergency Preparedness	A program for assuring a high state of preparedness for responding to an emergency is maintained to minimize the impact on the health and safety of the public and on plant workers if an emergency were to occur through the establishment of onsite and offsite Emergency Response Organizations, establishment and maintenance of emergency response facilities and equipment, development of Emergency Response Plans (including severe accident management guidelines and coping strategies) for onsite response and offsite interfaces, and the conduct training in both classrooms and drills of emergency response personnel to ensure readiness for emergency response.
14	Employee Assistance Program (EAP)	A		Human Resources	A program that offers professional guidance to employee and employee family members when personal problems become difficult to manage alone, including free assessments, short-term counseling, and referral information to employees and their family members, in order to address issues before they begin to affect job performance.
15	Employee Concerns Program (ECP)	A		Legal	A program supporting a healthy nuclear safety culture by providing employees and contractor workers with an alternative and independent process to seek intervention, consultation, or independent resolution of nuclear safety concerns in cases where individuals feel they are uncomfortable or unable to raise issues to management.
16	Environmental Qualification (EQ)	R		Engineering	A program to demonstrate compliance with design and regulatory requirements that assure equipment covered under the program can perform required functions under the harsh environmental service conditions that can exist during certain design-basis accidents in order to avoid common cause failures and the monitoring of installed components to assure they retain sufficient margin to support functional requirements through the projected end of component life.
17	Erosion and Corrosion Monitoring	T		Engineering	A program often conducted in conjunction with the FAC program for monitoring non-FAC wear in piping from erosion mechanisms that include cavitation, flashing, liquid droplet impingement (LDI), and solid particle erosion (SPE), which, similarly to FAC, can result in material degradation of affected systems resulting in wall loss, leaks, and pipe ruptures.

#	Program (Provided in alphabetical order)	Type	Tech.	Function	Definition
18	Export Control	T		Export Control	A program to assure compliance with the relevant international obligations and other commitments, including contractual commitments, to protect nuclear-related information, components, and substances, which are received in the implementation of a Civil Nuclear Energy Program, including nuclear-related scientific and technical information, technology, equipment, and materials, which may be export controlled or export prohibited under the nuclear-related agreements or other commitments.
19	Field Observation	A		NPI	A program to assure a strong leadership presence in the field performing focused behavior-based observations to reinforce high standards, strengthen organizational alignment to expected standards of excellence, and instill a culture of meeting commitments by requiring supervisors, managers, and senior managers to be in the field with employees each regularly scheduled working day to identify behavioral and standards gaps that reveal themselves as work is conducted.
20	Fire Protection	R		Fire Protection	A program for oversight and implementation of activities that assure nuclear generating facilities are protected from fire and can achieve safe shutdown including those activities associated with fire hazards analysis, detection and suppression system design and performance, and mitigation of the potential for fire initiation.
21	Fitness for Duty (FFD)	R		HR / Security	A program to provide reasonable assurance that nuclear facility personnel are trustworthy, will perform their tasks in a reliable manner, are not under the influence of any substance, legal or illegal, that may impair their ability to perform their duties and are not mentally or physically impaired from any cause that can adversely affect their ability to safely and competently perform their duties.
22	Fuel Integrity	T		Reactor Engineering	A program for achieving and maintaining a high level of nuclear fuel reliability, which is the first barrier to fission product release, in order to reduce the potential for the off-site release of radioactive material, plant personnel radiation exposure and contamination events, simplify plant operation and maintenance activities, improve efficiency in refueling activities, decrease low-level radioactive waste generation, and contribute to improvements in generation.

#	Program (Provided in alphabetical order)	Type	Tech.	Function	Definition
23	Health & Safety	T		Health & Safety	A program designed to prevent accidents and occupational diseases through the use of health and safety rules, correct work procedures, employee training in health and safety practices, workplace inspections, reporting and investigation of accidents/incidents, establishment of emergency procedures, provision of medical and first aid, and health and safety promotion.
24	Human Performance (HU)	A		NPI	A program of tools and techniques designed to minimize human errors and eliminate personnel initiated events.
25	In Service Inspection (ISI)	R		Engineering	A program employing a multifaceted methodology to meet ASME Section XI inservice inspection requirements across a 10-year interval, including the management of periodic scheduling of inspections using volumetric exams, surface exams, and visual inspection techniques to detect and repair flaws in piping and pressure vessels before they can compromise the structural integrity of the component.
26	In Service Testing (IST)			Engineering	A program for the conduct of examinations and tests in accordance with the ASME Operations and Maintenance (OM) Code of pumps and valves (including pressure relief devices, which protect systems or portions of systems that ensure integrity of the reactor coolant pressure boundary); which are classified as ASME Code Class 1, Class 2, and Class 3 or equivalent; and are required to perform specific functions to shut down the reactor to a safe shutdown condition, maintain the reactor in the safe shutdown condition, or mitigate the consequences of an accident.
27	Language Program (e.g. English)	A		Orgnizational Effectiveness	A program within multilinguistic, multicultural organizations for the assessment and continuous improvement of proficiency in the chosen language for plant operation to assure complete, accurate, and fully comprehended communications during normal, transient, and accident conditions.

#	Program (Provided in alphabetical order)	Type	Tech.	Function	Definition
28	Maintenance	T		Maintenance	A cross-organizational program involving engineering, operations, work management, radiation protection, chemistry, and other groups that, collectively, maintain the mechanical, electrical, and instrument and control equipment of the power plant to assure high standards of equipment performance and reliability are achieved through timely identification, screening, scoping, planning, scheduling, preparation and execution of work necessary to maximize the availability and reliability of station equipment and systems; managing the risk associated with work; identification of the effects of work to the station and work groups; protection the station from unanticipated transients resulting from work; and maximization of the efficiency and effectiveness of station personnel and material resources.
29	Maintenance Rule	R		Engineering	A program for deciding which of the many Systems, Structures, and Components (SSCs) that make up a commercial nuclear power plant need plant-specific risk significance and performance criteria established to be used to decide if monitoring and goals are needed to improve performance for specific SSCs covered by the program.
30	Motor Operated Valves	T		Engineering	A program for demonstrating both design basis functional capability and operational readiness with safety-related motor operated valves that are typically actuated by safety-related and environmentally qualified motor- and gear-driven actuators, including gate valves (flex and solid wedge and parallel double disc designs), globe valves (unbalanced and balanced disk), and butterfly (quarter-turn) valves – essential program elements include scoping and risk categorization; identification of design basis functional requirements; design inputs and evaluation/sizing methodology; required thrust, torque and functional margin calculations; MOV actuator switch setting and set-point control; periodic verification testing; periodic MOV actuator preventative maintenance; and tracking and trending and program feedback.
31	Offsite Dose Calculation	R		Environmental	A program establishing the methodology and parameters used in the calculation of offsite doses resulting from radioactive gaseous and liquid effluents, in the calculation of gaseous and liquid effluent monitoring alarm and trip setpoints, and in the conduct of radiological environmental monitoring controls and containing the radioactive effluent controls, radiological environmental monitoring activities, and descriptions of the information that should be included in the Semiannual Radiological Environmental Operating and Radioactive Effluent Release Reports.

#	Program (Provided in alphabetical order)	Type	Tech.	Function	Definition
32	Operating Experience (OE)	A		NPI	A program to use the lessons learned and insights from events effectively and efficiently to improve safety and reliability by analyzing both station and industry experience to identify fundamental weaknesses and then determining appropriate station-specific actions that will minimize the likelihood of or reduce the consequences of similar events.
33	Performance Assessment	A		NPI	A program of systematic performance review to include internal self-assessment and independent external assessment.
34	Probabilistic Risk Assessment (PRA)	R		Nuclear Risk Assessment	A program to quantify the risk of system failures, identify significant core damage and risk sequences, identify potential vulnerabilities to core damage and containment performance, and identify risk-important systems, components, or operator actions by use of event trees and fault trees, or, similarly, on Bayesian networks to identify failure scenarios, compute their probabilities, combining the probabilities of events and the distributions of random variables involved to evaluate the consequences of the failure scenarios, and then to use the results as input for risk management to optimize resource allocation (e.g., to minimize the probability of system failure given budget and system failure given budget and schedule constraints) and to check that, in the end, the failure risk is tolerable.
35	Process Control	A		RW Management	A program that establishes the administrative and operational controls for dry and wet (but, generally, not mixed) radioactive waste processing, process parameters, and surveillance requirements, which assure that the final waste product meets applicable regulatory requirements including methods to minimize the quantity of radioactive waste produced (volume and/or activity).
36	Quality Assurance (QA)	T		Quality Assurance	A program establishing and implementing the quality assurance requirements necessary to achieve safe, reliable, and efficient use of nuclear energy and management and processing of radioactive materials, focusing on the achievement of results, emphasizing the role of the individual and line management in the achievement of quality, and fostering the application of these requirements in a manner consistent with the relative importance of the item or activity.

#	Program (Provided in alphabetical order)	Type	Tech.	Function	Definition
37	Radiation Protection (RP)	T		Radiation Protection	A program for monitoring radiological conditions, control of radiological work, and managing radiological risk, including maintaining exposure As Low As Reasonably Achievable (ALARA), control of radiation sources, and management of radiological waste.
38	Reactor Vessel Integrity Program	R		Engineering	A program to assure the material integrity (i.e., fracture toughness) of the reactor vessels (consisting of the reactor vessel (shell and weld materials), the reactor core, core components (e.g., core neutron flux suppression inserts), surveillance capsules, and reactor coolant system (RCS) piping and connected piping/components relied upon for low temperature overpressure protection (LTOP) concerns) in consideration of radiation-induced embrittlement and encompassing reactor vessel neutron fluence projections, reactor vessel material surveillance capsule, pressurized thermal shock (PTS), reactor coolant system pressure/temperature limit curves (i.e., heat-up and cool-down curves), upper shelf energy, and low temperature overpressure protection system (LTOP).
39	Safeguards	R		Safeguards	A program for the protection of sensitive unclassified information concerning the physical protection of operating power reactors, spent fuel shipments, strategic special nuclear material, or other radioactive material.
40	Steam Generator Management	T	Not BWR	Engineering	A program is designed to provide and establish the means to assure that the SGs satisfy the requirements for structural and leakage integrity at all times in accordance with the Technical Specifications, ASME Code, NEI 97-06, Steam Generator Program Guidelines (or equivalent), and associated industry guidelines (such as EPRI) and regulatory requirements consisting of a balance of prevention, inspection, repair, maintenance, and leakage monitoring identify, maintain, and protect the SG design and licensing bases, establish a standard process for SG inspection and repair activities, and implement the Technical Specifications in order to achieve long term SG availability.

#	Program (Provided in alphabetical order)	Type	Tech.	Function	Definition
41	System Health Program (SHIP)	T		Engineering	A program for the integration and coordination of a broad range of equipment reliability activities into one process so that plant personnel can evaluate important station equipment, develop and implement long-term equipment health plans, monitor equipment performance and condition, and make continuing adjustments to preventive maintenance tasks and frequencies based on equipment operating experience, including activities normally associated with such programs as reliability centered maintenance, preventive maintenance (periodic, predictive, and planned), Maintenance Rule, surveillance and testing, life cycle management (LCM) planning, and equipment performance and condition monitoring. Reference AP-913, Equipment Reliability Process
42	Training & Qualification	T		Training	A program incorporating instructional requirements, including a systematic approach to training (SAT) to qualify personnel to operate and maintain the facility in a safe manner in all modes of operation, that are developed and maintained in compliance with the facility license and applicable regulations, are periodically evaluated and revised to reflect industry experience and to incorporate changes to the facility, procedures, regulations, and quality assurance requirements, and are periodically reviewed by management for effectiveness.
43	Margin Management	T		Engineering	A program for the identification and documentation of engineering margin (the difference between operating parameters, design limits, and failure points that account for uncertainties in KNOWN variables) and the margin of safety (design features incorporating redundancy and diversity to account for UNKNOWN variables) such that design features and assumptions are preserved to assure protection of the health and safety of the public.
44	Flow Accelerated Corrosion (FAC)	T		Engineering	A program to implement long term monitoring of high energy carbon steel components including predicting, locating, and repairing or replacing wearing components before minimum wall thickness code requirements are violated due to a chemical process that results in the wall thinning of carbon steel piping exposed to turbulent, flowing water or wet steam.to provide assurance that structural integrity is maintained.
45	Plant Lay-up and Preservation	A		Chemistry	A cross-organizational program involving Engineering, Operations, Work Management, Maintenance, Radiation Protection, and other areas to implement and support programs that control corrosion, minimize radiation dose rates, protect the environment, and help maintain reliable equipment performance.

#	Program (Provided in alphabetical order)	Type	Tech.	Function	Definition
46	Underground Piping and Tank Integrity (NEI 09-14)	T		Engineering	A program for assuring that risk significant (i.e., those important to plant operation, nuclear, and environmental safety) piping that is below grade (including buried piping below grade and in direct contact with the soil), not accessible, and outside of buildings and underground tanks (including abandoned tanks connected to active systems) outside of buildings and sufficiently below grade such that there is a reasonable possibility that leakage from inaccessible portions of the tank may not be detected and the cathodic protect systems protecting them are maintained to increase the reliability of underground piping and tank systems exposed to various environments in order to reduce online leakage and maintenance for unplanned or unnecessary repairs.
47	Welding	T		Maintenance	A program to assure that plant welding activities are controlled and performed in accordance with applicable codes and standards, Technical Specifications, and other governing documents to meet predefined quality standards to ensure that components fabricated, installed and repaired by welding are capable of performing their design and safety functions including comprehensive provisions to support welding activities on all plant components, safety and non-safety.

Appendix 2: Operating Model Essentials

Recommended List of Essential Documents

1. Procedures Writers Guide
2. Key Policies
    a. Operating model - an integrated management system including document structure/hierarchy)
    b. Nuclear safety policy (reactor, environment, industrial, radiological, security)
    c. Human resource/Talent management
    d. Stakeholder interface/Regulatory interface
    e. Business ethics/Code of conduct
3. Delegations of authority - financial, procurement, hiring, etc.
4. Organisational charts with job descriptions
5. Benchmarking guidance
6. Suite of commissioning guidance documents and associated administrative tools
    a. Turnover standards for plant system and area turnover from construction to commissioning.
    b. Turnover standards for plant system and area turnover from commissioning to operations.
7. Key operational standards and expectations
    c. Conduct of operations
    d. Conduct of engineering
    e. Conduct of maintenance
    f. Conduct of radiation protection
    g. Conduct of chemistry
    h. Conduct of training
    i. Conduct of reactor engineering
    j. Conduct of nuclear performance improvement
    k. Conduct of emergency preparedness
    l. Conduct of system/area turnover - transition through commissioning
8. Quality assurance (QA) manual
9. Process description for each process including implementing procedures
10. Program description for each program including implementing procedures

11. Event definition and determination

12. Reporting requirements manual - a comprehensive list that includes all incident notifications and performance reporting required by all stakeholders.

Appendix 3: Operational Readiness Planning Timeline – Basis

This appendix provides several illustrative sources of planning or actual industry new nuclear construction project performance data, information and insight.

Essential to our analysis are the following milestones:

1. First Concrete (safety-related) Date (FCD)
2. Start of Hot Functional Testing (HFT)
3. Fuel Load (FL)
4. First Grid Connection (FGC)
5. Start of first maintenance/refuel outage (R/MO)

To support our planning for the journey to operational readiness, the illustrations and follow-on summary analysis will provide us essential timing information as follows:

A. Planning duration of time from FCD to start of HFT
B. Planning duration of time from FCD to FL
C. Planning duration of time from FCD to first grid connection (FGC)
D. Planning duration of time from FCD to the start of the first maintenance/refuel outage (R/MO)

The three illustrations that follow will help us answer questions A through D.

Illustration 1: Real Company Planning Milestones Example

Construction efforts in China have been very efficient over the past 10 years. Effective and efficient execution typically follows quality planning and scheduling. Planning and scheduling includes establishing target milestones. One Chinese nuclear company uses the following construction project planning milestones and expected timings.

For each construction project, individual plant performance is assessed against these milestones:

Operational Readiness Preparation Milestones			
PHASE	MILESTONE NAME	PLANNING TIME	
		Reference	Actual
PHASE PREPA-RATION	FCD: First Concrete Day	FCD+0	
	Start Operations Preparations	FCD+3	
	Starting Writing Technical Procedure	FCD+12	
PHASE	Prepare Hand Over of System	FCD+18	
	Reviewing the Document of Simulator Test	FCD+22	
	Begin Single System Commissioning	FCD+25	

EXECUTION	Simulator Tests Before Delivering	FCD+26	
	Staff Shift Crews in Main Control Room (MCR)	FCD+28.5	
	Simulator Tests at Site	FCD+33	
	Simulator Available	FCD+34	
	Main Control Room (MCR) Ready	FCD+38	
	Cold Functional Test (CFT)	FCD+40	
	Hot Functional Test (HFT)	FCD+42	
	First Batch of MCR Operators Passed Licence Test	FCD+42	
	First Loading Fuel in Core (FL)	FCD+48	
	First Reactor Criticality	FCD+50	
	Initial Turbine Run Up	FCD+50.5	
	Connection to the Grid (FGC)	FCD+51	
	Ready for Commercial Operation (COD)	FCD+54	

Source: New Unit Assistance Working Group

Illustration 2: IAEA Industry Data 2010 to 2019

Data in the table below comes from the IEAE PRIS database. It summarizes the actual construction times for projects completed between 2010 and 2019. To make the data more meaningful as it relates to our purposes, we have excluded projects with unusual circumstances leading to abnormally long project durations.

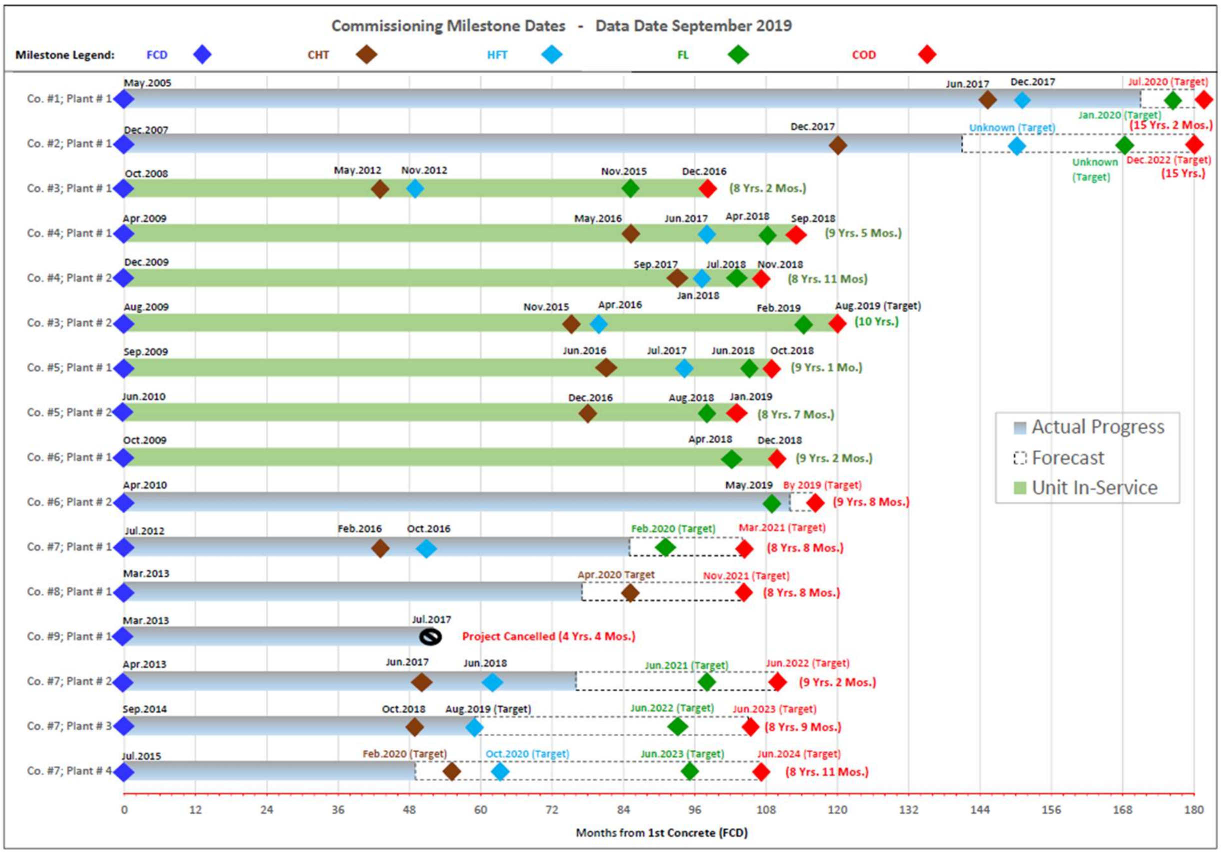
Region	# of Reactors	Median (Months)	Average (Months)	Average (Years)
Asia - Far East	41	66	72	6
Asia - Middle East and South	7	86	99	8.25
Europe - Central and Eastern	7	106	100	8.33
World Wide	55	67	79	6.58

Source: New Unit Assistance Working Group

The construction period is defined here as the period of time from the first major placing of concrete for the base mat of the reactor building to the date on which the plant is first connected to the electrical grid (FGC) for the supply of power. After this date, the plant is considered in operation.

Illustration 3: Detailed Milestone Study – 16 Recent New PWR Reactors

The chart below contains data on 16 new nuclear construction projects that have recently been completed or will be in the next two years. The data provided includes the time to completion of CHT, HFT, FL and COD. Summary information is provided in the accompanying table.



One project in this study was cancelled. Its data has been excluded from the analysis that yielded the summary data below. For the remaining 15 projects completed and/or progressing toward completion, the following times (in months) have been achieved (or are reasonably projected to be achieved).

Start Activity	Completion Activity	Average Duration (Months/Years)	Earliest Time Achieved (Months/Years)	Longest Time Achieved (Months/Years)
Safety-Related Concrete Poured (FCD)	Start of Cold Hydrostatic Testing (CHT)	78	43	145
Safety-Related Concrete Poured (FCD)	Start of Hot Functional Testing (HFT)	85 / 7.1	49 / 4.1	151
Safety-Related Concrete Poured (FCD)	Start of Fuel Load (FL)	102 / 8.5	85 / 7.1	114

Source: New Unit Assistanc Working

Safety-Related Concrete Poured (FCD)	Commencement of Commercial Operation (COD) *	107	98	113
Completion of Hot Functional Testing (HFT)	Start of Fuel Load (FL)	16	15	33
Fuel Load	Commencement of Commercial Operation (COD)	7	5	13

Source: New Unit Assistanc Working Group

Note: *In this study, the commencement of commercial operation follows the first connection to the grid. To determine first connection to grid, we will subtract three months from commencement of commercial operation to allow for various forms of post-grid connection testing, reliability outages, contractual terms, and/or transmission system rules and expectations.

Summary Analysis:

Information and insights from the three illustrations can be summarized as follows:

A. Planning duration of time from FCD to start of hot functional testing (HFT)

B. Planning duration of time from FCD to fuel load (FL)

C. Planning duration of time from FCD to first grid connection (FCG)

D. Planning duration of time from FCD to the start of the first refuel outage (R/MO)

Given the desire to be operationally ready when the plant is, it is conservative to prepare early. This assumption is allowed for in the planning determinations shown in the chart below.

The chart data is shown in months

Questions A - D	A	B	C	D	
	HFT	FL	FGC	RFO **	Notes
Illustration # 1	42	48	51	63	Planning Basis
Illustration # 2			79 (72)	91	WW Actual (East Asia)
Illustration # 3 - Average	85	102	107	119	Actual / Projections
Illustration # 3 - Early	49	85	98	110	Actual / Projections

Planning Determination	48	66 *	72	84	

Source: New Unit Assistanc Working Group

Table Notes:

1. *Fuel load determination based on the subtraction of a 6-month average duration taken from illustration #3 from the 72-month average duration to FGC. Six months is twice the example planning duration.
2. **The start of the first refuel/maintenance outage is calculated simply by adding an assumption for the duration of the first operating cycle. The duration of this typically shortened first cycle of operation is established to be 12 months after FGC.

Conclusion: Our journey to operational readiness needs to assume that from the pour of first concrete, the plant will be ready to conduct HFT in 48 months (4 years) and be ready for FL in 66 months (5.5 years). Similarly, the plant will achieve FGC in 72 months (6 years) and conduct its first R/MO 12 months later.

Note: Some projects have demonstrated even better schedule execution during specific portions of their schedule. Example: One company in the study progressed from FCD to start of CHT in 35 months. Another project progressed from CHT to commercial operation in 15 months. These experiences suggest that even earlier project completion is achievable, perhaps as early as 50 months from FCD to FGC. While possible, this premise is untested and unlikely.

A note about an important data source:

The IAEA provides us with the Power Reactor Information System, or PRIS. This publicly available database of information is accessible here: https://pris.iaea.org/pris/. This database contains construction start and FGC dates for all units worldwide. End user reports can be created from this source. Help is available generating reports and analysing data from IAEA personnel as required.

For information by plant, you can access this same data via the World Nuclear Association's (WNA) user-friendly, graphical interface referenced here:

http://www.world-nuclear.org/information-library/facts-and-figures/reactor-database.aspx

A public example of this output is provided for illustration:

Sanmen 1 (AP1000, China) http://www.world-nuclear.org/reactor/default.aspx/SANMEN-2

Details	
Reactor Type	Pressurised Water Reactor (PWR)
Model	AP-1000
Owner	China National Nuclear Corporation
Operator	Sanmen Nuclear Power Co., Ltd.
Timeline	
Construction Start	15 December 2009
First Criticality	17 August 2018
First Grid Connection	24 August 2018
Commercial Operation	5 November 2018

Source: IAEA PRIS Database Output

Appendix 4: Operations Organization Staffing Curve - Basis

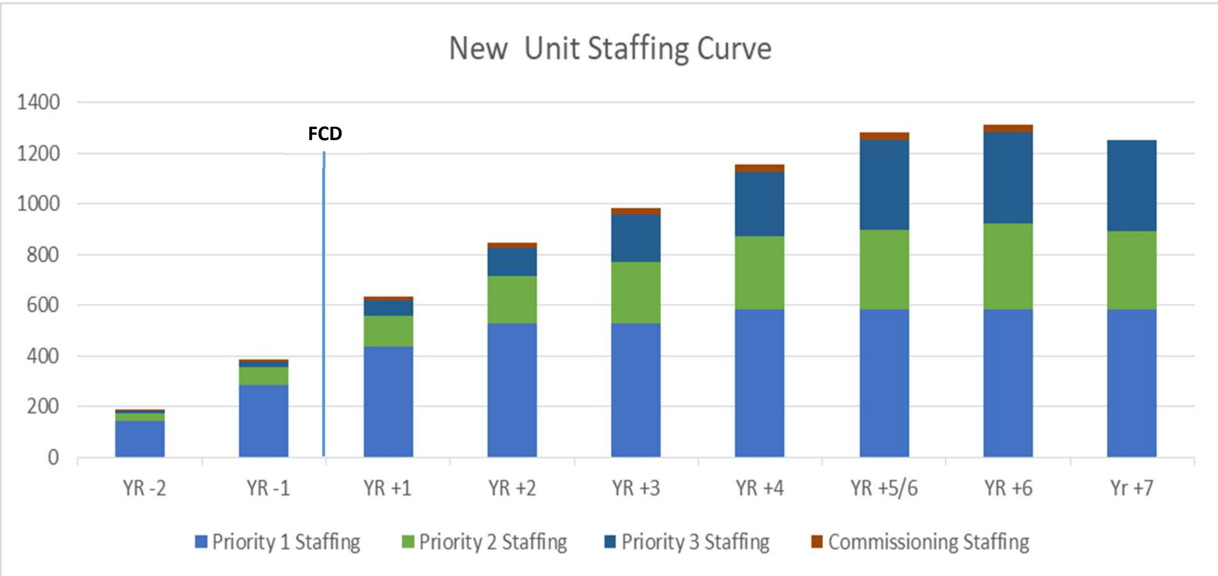
Functions should be staffed in approximately the priority shown below:

		Plant Licensing	Construction	
		ECD	FCD	HFT
		YR - 2 YR - 1	YR + 1 YR + 2	YR + 3 YR + 4
	Functional Area	Priority 1	Priority 2	Priority 3
1	Administration (Administrative Support)	X		
2	Chemistry	X		
3	Commissioning Oversight (Temporary)		X	
4	Communications	X		
5	Decommissioning			X
6	Document Control & Records Management	X		
7	Emergency Preparedness		X	
8	Engineering	X		
9	Environmental Management	X		
10	Export Controls		X	
11	Facilities Management / General Services		X	
12	Finance	X		
13	Fire Protection (includes Fire Response Team)		X	
14	Fuels	X		
15	Health and Safety	X		
16	Human Resources	X		
17	Information Technology (IT)	X		
18	Integrated Management System	X		
19	Internal Audit (IA)		X	
20	Legal		X	
21	Licensing & Regulatory Affairs	X		
22	Maintenance		X	
23	Management (Senior and Executive level)	X		
24	Nuclear Oversight			X
25	Nuclear Performance Improvement (NPI)		X	
26	Nuclear Risk Management	X		
27	Operations	X		
28	Organizational Effectiveness (OR)		X	
29	Plant Projects			X
30	Procurement & Supply Chain	X		
31	Program Management	X		
32	Quality Assurance	X		
33	Radioactive Waste Management			X
34	Radiological Protection			X
35	Reactor Engineering			X
36	Safeguards		X	
37	Security		X	
38	Training	X		
39	Work Management			X

Source: New Unit Assistanc Working Group

Using the priority scheme above and referencing the process and program priority guidance shared in Section D, the following employee hiring profile by function has been established.

	Functional Area	YR -2	YR -1	YR +1	YR +2	YR +3	YR +4	YR +5/6	YR +6	Yr +7
		ECD		FCD						
		Priority 1		Priority 2		Priority 3				
		Contract / License		Construction				HFT	S/U	Op Cycle
1	Administration (Administrative Support)	4	8	16	24	25	26	28	28	28
2	Chemistry	12	23	35	41	41	46	46	46	46
3	Commissioning Oversight (Temporary)	5	10	15	20	25	30	30	30	
4	Communications	2	3	5	5	5	6	6	6	6
5	Decommissioning	1	1	1	1	1	1	1	1	1
6	Document Control & Records Management	4	8	12	14	14	16	16	16	16
7	Emergency Preparedness	1	3	5	10	15	18	20	20	20
8	Engineering	21	43	64	77	77	85	85	85	85
9	Environmental Management	3	5	8	9	9	10	10	10	10
10	Export Controls	1	2	2	2	3	4	4	4	4
11	Facilities Management / General Services	1	1	3	5	8	9	10	10	10
12	Finance	3	5	8	9	9	10	10	10	10
13	Fire Protection (includes Fire Response Team)	1	6	15	29	44	52	58	58	58
14	Fuels	3	5	8	9	9	10	10	10	10
15	Health and Safety	3	5	8	9	9	10	10	10	10
16	Human Resources	8	15	23	27	27	30	30	30	30
17	Information Technology (IT)	8	15	23	27	27	30	30	30	30
18	Integrated Management System	1	1	2	2	2	2	2	2	1
19	Internal Audit (IA)	1	1	2	4	6	7	8	8	8
20	Legal	1	3	4	5	5	5	5	5	5
21	Licensing & Regulatory Affairs	3	5	8	9	9	10	10	10	10
22	Maintenance	1	10	48	95	143	171	190	190	190
23	Management (Senior and Executive level)	3	5	8	9	9	10	10	10	10
24	Nuclear Oversight	1	1	1	1	2	3	6	6	6
25	Nuclear Performance Improvement (NPI)	1	3	4	8	11	14	15	15	15
26	Nuclear Risk Management	1	2	2	3	3	3	3	3	3
27	Operations	48	95	143	171	171	190	190	190	190
28	Organizational Effectiveness (OR)	1	1	1	2	3	4	4	4	4
29	Plant Projects	1	1	1	1	3	5	10	10	10
30	Procurement & Supply Chain	13	25	38	45	45	50	50	50	50
31	Program Management	3	5	8	9	9	10	10	10	10
32	Quality Assurance	3	5	8	9	9	10	10	10	10
33	Radioactive Waste Management	1	1	2	2	3	5	10	10	10
34	Radiological Protection	1	2	2	4	10	20	40	40	40
35	Reactor Engineering	1	1	2	2	3	5	10	10	10
36	Safeguards	1	1	2	2	3	4	4	4	4
37	Security	1	10	25	50	75	90	100	100	100
38	Training	25	50	75	90	90	100	100	100	100
39	Work Management	1	5	5	9	23	45	90	90	90
	Priority 1	144	287	435	526	527	584	586	586	585
	Priority 2	31	71	123	189	245	287	309	339	309
	Priority 3	7	19	60	114	184	254	356	356	356
	Special	5	10	15	20	25	30	30	30	
	Totals	187	387	632	849	981	1155	1281	1281	1250



Appendix 5: New Unit Industry Success Stories

A. Expanding Operations Simulator Capacity at Low Cost

B. Improving Emergency Operations with State-Oriented Procedures

C. Preventing Future Events with HU Training and Qualification

D. Preparing for More Effective Simulator Instruction

E. Changing Behaviours Using Dynamic Learning Activities (DLAs)

F. Employing the Model for Operational Decision-Making (ODM)

G. Conducting Operational Readiness Exercises

H. Implementing Chemistry Best Practices

I. Achieving Standards of Excellence in New Plant Material Condition

J. Leveraging Continuous Improvement Across Multiple Units

K. Conducting Transient-Free Plant Startup and Power Ascension Testing

A. Expanding Operations Simulator Capacity at Low Cost

Background:

This project consists of four large APR-1400 units. The schedule for these units assumed the construction, commissioning, and startup of these units in sequential order, one year apart. The project had planned for and built two (2) full scope training simulators (Fig. 1) to support the training and qualification of new control room operators and the conduct of emergency preparedness (EP) exercises. The demand for simulator training time was very high.

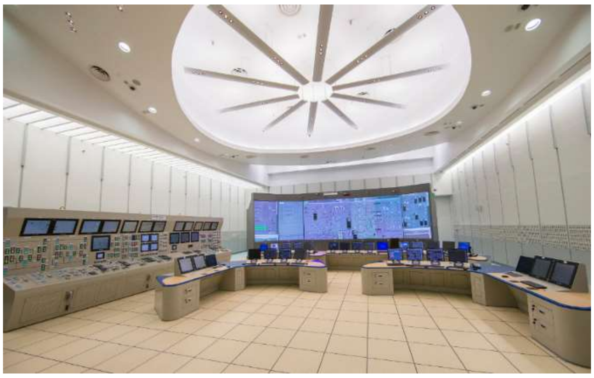


Fig. 1 APR100 Full Scope Simulator (FSS)

Source: Nawah Energy Company

Problem:

Early in 2016, the combination of operator simulator training needs, the conduct of EP drills, and the execution of routine simulator upgrades and maintenance, significantly exceeded the availability of the two site training simulators. The simulators were in use 24 hours a day, seven days a week. Greater simulator capacity was needed to satisfy excessive demands. The expanded capacity was needed quickly to prevent project delays.

Solution:

Build inexpensive, limited (or partial) scope simulators to expand the size of the training pipeline and remove challenges to the rate of staff qualification.

Description:

The simulator team developed four very sophisticated alternative designs and built what were called Limited Scope Simulators (LSS) (Fig. 2) and Partial Task Simulators (PTS) (Fig. 3).

The LSS is a complete mimic of a full scope simulator. It runs the exact same simulation software using much simpler hardware. The simulators were run from a common server using an emulated distributed control system. Scenario-based testing running complicated operational scenarios yielded results (including parameter trends and alarm actuation) that were 100% identical. The testing results garnered operator and regulatory support.

The original FSS used Barco projectors to drive large display panels. For the LSS, standard off-the-shelve LED screens were used that were driven by a wall controller. The LED screens had very small bezel to bezel resolution. Instead of using expensive engineering and safety control modules (ESCMs), the LSS employed standard off-the-shelf tablets and/or iPads. The operator console furniture was redesigned to make them proportionally smaller. A local supplier built them at a relatively low price. For the simulator safety console, a 75” multi-touch screen was configured to be a virtual panel and used instead of a conventional analogue safety console.

Fig. 2 APR100 Limited Scope Simulator (LSS)

Source: Nawah Energy Company

This optimization and redesign effort enabled project staff to design and construct a first LSS in April 2016, at a total cost of 150,000 USD in 4 months' time. The LSS was built within the existing training building facility in generic, multiuse floor space. For comparison, the construction cost for each of the existing FSS was approximately 10 Million USD (2.5 million for the FSS and 7.5 million USD for the FSS simulator building). A very significant savings was achieved.

This project was a major success. The risk to operational readiness delays was averted. Trainee feedback was very positive. All were achieved at low cost.

This success was replicated 7 months later in November 2016 to further augment simulator capacity. A third LSS was built in corporate headquarters (February 2019). A final LSS was built at site to support operation's plant procedure validation. In all, four LSSs were designed and built within existing facility spaces.

Additionally, the simulator team designed and configured more than 25 PTSs (Fig. 3) using identical FSS and LSS software. The PTSs were staged in multiple locations throughout the project facilities. The PTSs were used to conduct engineering design development tasks, develop and conduct job performance measures (JPM), simulator scenario and exam development, and task-specific training.

One key note: In 2011, the simulator team adopted and used an emulation approach to development of their simulator digital control system (DCS) versus the more conventional and traditional approach of stimulation. Without having done so, the development of the LSS and PTS would not have been possible.

Conclusion: The expansion of a program capacity to conduct high-quality simulator training can occur quickly and at low cost with proper levels of forethought and personnel creativity.

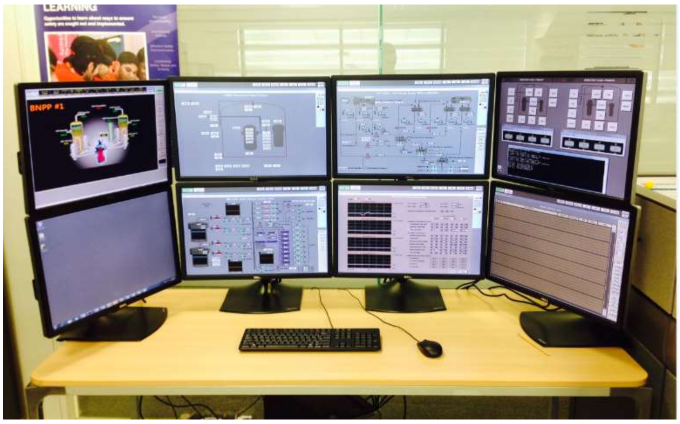


Fig. 3 APR1400 Partial Task Simulator (PTS)

Source: Nawah Energy Company

B. Improving Emergency Operations with State-Oriented Procedures

Background:

This plant featured a digital control system (DCS). The operations department had developed event-based, emergency procedures for use by operators in response to plant events and abnormal conditions. As expected, these procedures were used in simulator training to create operator proficiency when responding to plant events.

Problem:

Operators at the plant struggled to consistently and effectively manage complex event scenarios using event-based, emergency procedures. Narrow plant event entry conditions and prescriptive linear procedural guidance hindered operator understanding of plant conditions and undermined operator effectiveness when responding to plant events.

Solution:

The plant adopted the use of state-oriented, or symptom-based, procedures (SOP) for use with their plant's digital control system (DCS). SOPs were developed and implemented as follows to optimize use of the DCS system and help operators more effectively manage complex event scenarios.

1. SOP and support system screen design: Analysis was performed on the integrated use of emergency procedures with a DCS system with careful consideration of the human/machine interface. An SOP master procedure under a DCS was created. The main part of the SOP sequence used a paper format. Operational modules were extracted from the sequences and operating mode sheets (MOPs) were developed and digitized. The main part is in paper form so that operators can fully master the procedure and know the whole situation. At the same time, a special state display screen (YST screen) was designed and implemented to help operators monitor plant conditions as well as accident conditions. The digitized MOPs are designed to leverage the DCS. In addition, special logic judgment screens and auxiliary operation screens (YBD and YFU screens) were designed to improve operator use and efficiency.
2. Validation of SOP: The plant adopted four validation methods to verify the quality of SOP. These were:
    1. On-site validation
    2. Static simulator validation
    3. Dynamic simulator validation
    4. Dynamic validation by COC/BAS test, so as to ensure the correctness and enforceability of the procedure.

    - On-site validation using on-site operation sheets was performed to verify the accuracy of all the equipment listed. Equipment functions, locations, labelling and the appropriateness of designated tooling when applicable was validated.
    - Static simulator validation was performed to check for potential issues in the digitization process of DCS-based SOPs and their supporting screens. These were table top, walk-through exercises using a static simulator, the procedures and all applicable screens.

- Dynamic simulator validation was performed to check the correctness and enforceability of the SOP under accident conditions and the appropriate coordination of procedure use by all operator roles in main control room. These were dynamic simulator exercises using a live simulator, the procedures and all applicable screens.
- Dynamic testing was conducted for a loss of plant instrumentation and/or loss of site electrical power scenarios to verify proper plant (and simulator) response, including the automatic actions of all systems and equipment.

Continuous improvement:

Upon implementation, the plant established a nuclear safety issue answer sheet system by which operators and simulator instructors could identify procedure or screen problems or pose questions and concerns when using SOPs. The SOP preparation department subsequently collected, reviewed and analysed all issues and routinely upgraded the SOP to optimize performance.

Conclusion:

The DCS-based SOPs at this plant were found to improve operator performance when addressing complicated plant event scenarios.

C. Preventing Future Events with HU Training & Qualification

Background:

This project consists of four large APR- 1400 units. The operating staff peaked at approximately 2,500 persons. It is a multicultural staff representing over 43 different countries, predominated by the local citizenry (approximately 45%) and that of its operating partner staff (approximately 30%).

The Problem:

As the organization progressed through plant construction toward commissioning and eventually plant operation, events began to occur. A primary objective of any strong nuclear operation that values safety is the prevention of site and plant events. Establishing the proper behaviours to help prevent events is a challenge for any new operating organization. It is even more challenging in a broadly diverse, multilingual organization.

The Solution:

The project embarked on a number of people-focused programs, including the development and implementation of a comprehensive HU program. The goal of the HU program is event-free operation. Preventing events requires minimizing human errors. Use of a suite of HU tools are an important behavioural expectation of every nuclear professional within the operating organization. The HU program works tirelessly to embed these behaviours into the everyday working culture at the site.

Description:

The HU program was not created in isolation. A team of HU subject matter experts (SMEs) from Canada, the UK, South Africa and the U.S. was hired and/or contracted in support of program development and implementation. These HU program experts bench marked and studied the HU programs of the world’s strongest nuclear operators. Benchmarking targets were identified by WANO who pointed out the world’s top performing nuclear operators with strong HU programs. The program experts also sought out and referenced relevant WANO guidance in human performance. Upon completion of these initial efforts, the collected guidance was studied and analysed. A comprehensive, systematic approach to human performance was developed for review, approval, and subsequent implementation. The HU program was developed and implemented more than four years prior to fuel load and plant operation and at a pace to match the construction schedule. Early use of the HU program included plant fuel receipt and the start of HFT.

Oversight of HU program development and implementation was accomplished by a Human Performance Oversight Committee (HUOC). This committee was represented by all the core operating functions from across the organization and was led by the chief nuclear officer. This committee endeavoured to meet several objectives:

- Review, refine and approve detailed program guidance in support of planned implementation.
- Create leadership alignment across the organization to embrace event prevention and the use of HU tools.
- Oversee program implementation and take action as necessary to augment efforts and address performance shortfalls against program expectations.

Most importantly, the effort to finalize program governance included the definition of a suite of HU tools (See basic HU tool guidance provided in the functional section for nuclear performance improvement).

Once the program and associated HU tools were defined, a systematic approach to training was established in support of program implementation. An expectation was established that all operating organizational personnel would be trained and formally qualified in the use of the HU tools. Qualification was established based on the completion of annual training, passing a written test, and the successful demonstration of the use of the skills. Both the training and examination of the HU tools incorporated dynamic learning activities (DLAs) using an assortment of simulations and mock ups. An example of this can be seen in the inserted photo captured in Figure 1. Training and qualification are required annually.

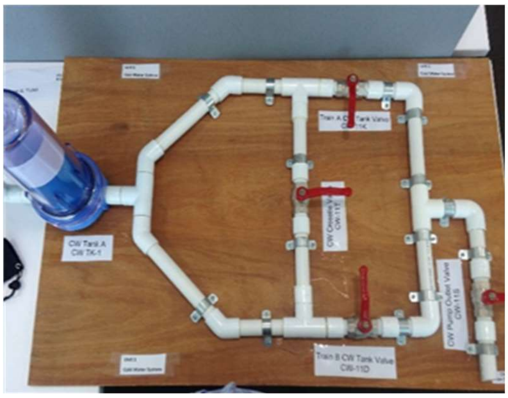


Fig. 1 HU dynamic learning activity simulation tool example

Source: Nawah Energy Company

Annual training consisted of one eight-hour training day. This day included the following:

- Two to three hours of classroom instruction.
- Three hours of dynamic learning and practice using the physical simulation and mock-up tools.
- Written and practical examination. Individual examination failure required remediation and retest.

This one-day HU training session and examination was eventually incorporated into the very first week of new employee indoctrination. This sent a strong message to new employees regarding the plant's objective regarding event prevention and expectations for staff use of the HU tools.

To be successful ingraining consistent employee use of the HU tools, reinforcement by management for the use of HU tools in the field was required. A robust observation program was developed and implemented. All managers were required to conduct and document two formal observations monthly. A key focus of the program would be use of the HU tools. Support for this program included leadership training in the use of observation and coaching (O&C) techniques. Support also included the purchase and implementation of a formal observation software module. The software was set up so that leaders have a chance to review the submitted observations of their direct reports and ensure compliance and challenge observation performance quality. Early O&C program implementation focused on compliance. The program ramped up over six to nine months to consistently achieve a completion rate of leadership field observations of over 95% monthly. Leaders failing to meet expectations were addressed. The quality of field observations became the next area of organizational development. Program experts reviewed the documented observations against established quality criteria. An example of such a criterion included, "Was action taken to either resolve an issue identified, or reinforce a correct behaviour?" As expected, quality scores started low and grew with time. O&C program compliance numbers, graphs and trends were shared with the leadership team weekly. These interactions also included a review of both good and bad examples of quality observations. Eventually, the organization completed over 14,000 observations annually and did so at a quality rate of over 82% of observations. The O&C program helps the organization identify HU behavioural drift where it is occurring. It directs intervention actions where gaps in organizational performance are identified. Identified performance trends are shared with the organization in a “Focus of the Month” communication.

The objective of the HU program is to prevent events. To monitor such performance, several actions were required. A suite of HU performance metrics was developed. To accomplish this, several definitions were required to include what constitutes an event at a variety of significance levels. Site event guidance was developed again using WANO guidance. Site event-free event clocks were defined to capture major events. This standard allowed comparison to other nuclear plants across the world. In addition, the organization introduced department learning clocks (DLC) to enhance the normal CAP process by allowing departments, using their own specific criteria, to enhance team learning and performance. These DLCs not only capture lower level events and errors but also capture good catches within the organization to help foster the creation of a positive learning environment. (See figure 2)

All of the elements discussed in this success story are formally documented within the HU program governance procedures.

An effective human performance program includes well defined HU tools that are consistently demonstrated by strong and committed nuclear professional. Creating such an outcome demands continual executive support for the program and leadership team alignment and commitment.

Continuous improvement:

The HU program is routinely assessed as part of the plant’s site assessment program. Such assessments consider the rate of HU events (i.e. site clock resets), error rates, and emerging gaps noted in HU tool observations. Follow-on actions will include strategic initiatives where and when necessary. Planned next steps at this plant include the benchmark, development and implementation of paired observations and peer to peer observations.

Finally, the plant recognizes it is not alone in trying to embed the right safety behaviours and culture at the site. It actively seeks the help of industry operating colleagues and WANO peers to help identify further improvement opportunities. The plant strives for continuous improvement.

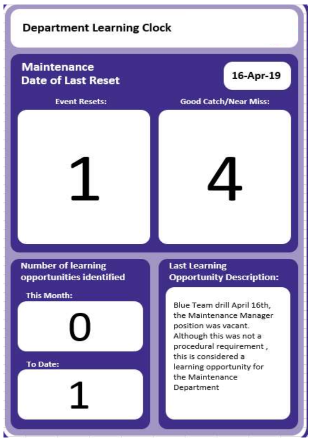


Fig. 2 Site Event Clocks highlight and communicate high level events. Department Learning Clocks (as shown above) highlight lower level events important to each department.

Source: Nawah Energy Company

Conclusion:

An early and rigorous approach to minimizing human errors is an important component in efforts to prevent future operating events and to build a healthy safety culture of nuclear professionals.

D. Preparing for More Effective Simulator Instruction

Background:

This is project is constructing two EPR reactors.

The Problem:

The operator training program had concerns about the quality, consistency and effectiveness of simulator training in support of operator licence training.

The Solution:

Develop and conduct a Simulator Instructor Foundation Training program for all operation simulator instructors.

Description:

Simulator instructors have a significant impact on both the technical competency and operational performance of future plant operators in the main control room (MCR). Not only do they continue the development of technical competencies begun in the classroom environment, they also influence future operator decision-making and professional behaviours to be demonstrated within the MCR.

In readiness to train and qualify operating crews within the simulator, first develop a strong approach to training simulator instructors. The plant developed and implemented a standalone, systematic training program to develop simulator instructors in preparation for delivering simulator training to MCR operators. The Simulator Instructor Foundation Training program developed consists of 5 steps sequenced approximately as follows:

Step 1: Verify Instructor Technical Competency – Simulator instructors must first possess a sound understanding of the plant technology to be taught. Simulator instructors were selected who possessed technical competencies developed during a combination of past technical training courses and operating experiences. Most importantly, simulator instructors subsequently completed a one-year reactor operator training course in pressurised water reactor operations (modified for the EPR design).

Step 2: Develop (or ensure) Simulator Instructional Core Capability – Simulator instructors participated in a formal one-week course to introduce and ingrain the basic principles of simulator training. This training included scenario development, simulator participant briefings, trainee observations, and the conduct of post-scenario critiques. Simulator instructors learned how to develop and execute simulator exercise guides (SEG). These important guides emphasise the use of core training principles and provide a basis for more consistent simulator instruction. The WANO Operator Fundamentals are embedded within the structure of the SEGs to help strengthen instructional effectiveness in pursuit of safe operational decision-making and nuclear professional behaviours.

Step 3: Ensure Simulator Instructional Consistency using Mentor Guides - Ten mentor guides were developed to ensure that all expected training materials and instructional tools were used by simulator instructors in a consistent and effective fashion. Simulator scenarios for major evolutions (e.g. startup, shutdown, etc.) were developed that direct the proper use of supporting simulator systems such as phones, camera systems and other scenario tools. Instructors must successfully conduct a number of SEGs applying the requirements of the mentor guidance provided. Success is evaluated and approved by senior staff. Feedback is provided.

Step 4: Develop Advanced Simulator Instructor Capability - A simulator instruction course was developed focusing on proper scenario development, simulator participant briefings, trainee observations, and the conduct of post-scenario critiques. This course (built to emulate a course originally offered by INPO) uses dynamic role-playing to allow student instructors the opportunity to practice their feedback and persuasion techniques in preparation for interface with real trainees.

Step 5: Verify Simulator Instructor Effectiveness Simulator instruction authorisation must be achieved through the successful completion of a formal assessment and evaluation. Each simulator instructor is required to produce a SEG to the required standards, prepare the simulator systems to use the SEG, and deliver training using the SEG while under direct oversight by senior staff. Upon successful completion of the various components, the instructor is authorised to perform simulator training duties.

The five steps above take a total of approximately 18 calendar months to be conducted completely and properly.

Conclusion:

Quality and consistent simulator instruction is essential to future operator performance. It is too important to leave to chance. A formal and systematic program like that developed and deployed for this plant project can help simulator instructors prepare and deliver high-quality simulator training to MCR operators.

E. Changing Behaviours Using Dynamic Learning Activities (DLAs)

Background:

This project consists of four, large APR-1400 units. The operating staff at the time was approximately 2,000 persons. Construction and commissioning staff were active in the plant as well. The combined staff were multicultural and represented over 80 different countries and cultures.

Late-stage construction activities were underway to include hot functional testing, fuel receipt, system turnovers to operation, and other preparations for fuel load. A management observation program had been developed and implemented and hundreds of observations were being conducted in the field monthly. Additionally, a worker-led safety committee, Team Safety, was formed and had initiated regular worker observations in the field. These activities identified issues that were captured within the observation program software and the corrective action process (CAP) program.

Problem:

As the number of observations and issues identified increased, several safety behaviour trends emerged within the CAP. Adverse trends in personal protective equipment (PPE) use, the proper operation of plant fire doors, foreign material exclusion (FME) practices, and component safety tagging were identified. Additionally, the pre-OSART assessment conducted by the IAEA noted some of these worker behaviours occurring in the field and made recommendations to address them.

Corrective action was required to address these troubling trends. It was recognized that unique action would be required to address these trends and correct behaviours in the broadly diverse plant staff. In addition to traditional supervisor actions and organizational communication and outreach programs, something more dynamic was required to help affect needed change.

Solution:

Traditional supervisor actions targeted the identified inappropriate worker behaviours. However, the extent and urgency of the problem required additional intervention. Team Safety met with personnel from the functions of nuclear performance improvement, nuclear oversight, organizational effectiveness, and health and safety. A collaborative effort created a process (depicted below) for the creation of dynamic learning activities (DLAs).

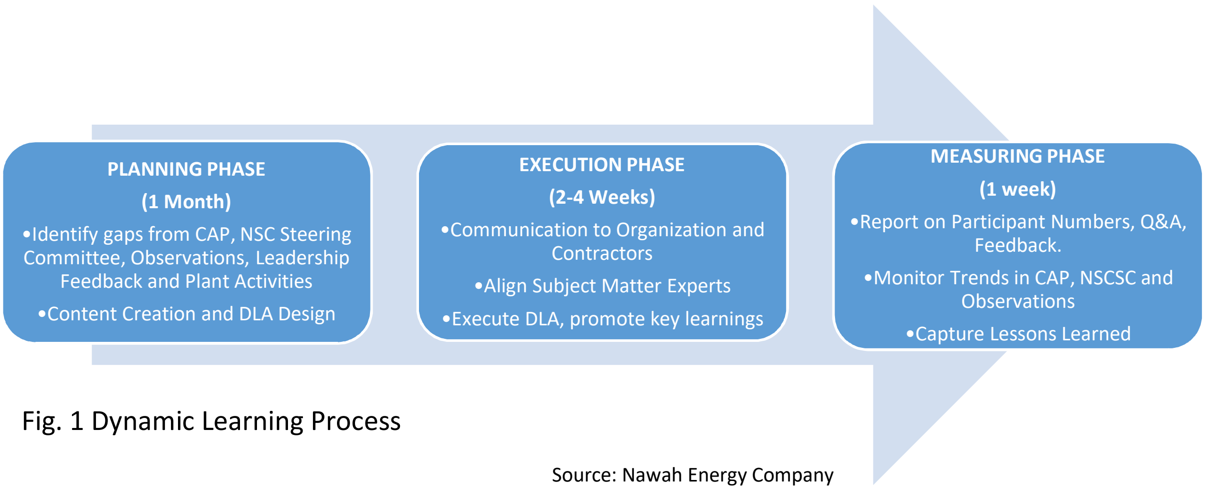


Fig. 1 Dynamic Learning Process

Source: Nawah Energy Company

This process converted identified issues into hands-on activities that were developed and implemented with the workforce. These activities were deployed in multiple ways. In the picture to the right, workers can be seen engaged in a dynamic fire door activity that was executed as workers arrived at work. Workers were required to answer questions and demonstrate the desired behaviour. Incorrect answers and behaviours were immediately corrected, and workers had to repeat the exercise. Proper answers and behaviours were immediately rewarded in multiple ways (e.g. drinks, morning snacks, t-shirts, etc.). Each person had to demonstrate the ability to fully close, latch and test the door latch. This process verified that workers from all functions understood why fire door closure was important. Such activities could address several hundred persons in a single morning. Multiple sessions in a week could address 80% of the plant worker population.

Fig. 2 Fire Door Dynamic Learning Activity

Source: Nawah Energy Company

DLAs were also developed and set up within the shop areas to address behavioural change within more targeted worker populations. A hands-on safety tagging exercise can be seen in the pictures that follow. This exercise verified worker understanding of each tag type and challenged their ability to apply and remove tags. It also challenged their willingness to remove a tag or operate a tagged component inappropriately. Each member of the targeted worker population was formally signed off to verify understanding and capability. This helped raise personal accountability.

Fig. 3 Safety Tagging Dynamic Learning Activity

Source: Nawah Energy Company

A third example of DLA activities were developed and deployed at the annual Nuclear Safety Fair. Nuclear Safety Fair events were conducted over the course of a week. All employed and contracted staff were invited as were external stakeholders to include the regulator and key government personnel. Thousands of people participated. The fairs were designed to prepare both internal and external stakeholders for the safe operation of the plant, and helped promote the use of the traits of a healthy nuclear safety culture. The fairs included numerous small-scale, hands-on learning activities. The DLA shown below required participants to demonstrate the use of human performance (HU) tools during a designed mock-up activity. Participants read preparatory materials, participated in a pre-job brief, conducted a job site review, and conducted an evolution using various verification techniques to include self-check, independent verification, and three-way communication. A post job brief was conducted which provided workers the opportunity to self-assess their performance against expectations.

Fig. 4 Human Performance (HU) simulation

Source: Nawah Energy Company

The process of DLAs was captured within the organization's governance documentation. The documentation included worksheets that guided proper DLA development, execution and effectiveness assessment. Additionally, DLAs were captured in a library for future reference. This documentation maintains the DLA as a tool in the leadership team's ongoing toolbox of intervention techniques.

Conclusion:

These dynamic exercises proved very effective in helping to change worker behaviours. When coupled with traditional supervisory actions, large-scale behavioural change in the plant was made and adverse trends were corrected.

The WANO plant startup (PSUR) review helped validate effective changes to the issues noted during the pre-OSART review conducted two years earlier. The assessment confirmed a real change in worker safety and helped validate the effectiveness of organizational leadership.

Fig. 5 Setup of for an FME Dynamic Learning Activity

Source: Nawah Energy Company

F. Employing the Model for Operational Decision-making (ODM)

Background:

This project is a multi-unit nuclear site with six 1000-Megawatt CPR-1000 pressurized water reactors.

In 2013, during preparations for the fuel load, startup and commissioning of unit 1, site management recognized shortcomings in plant decision-making. Plant events occurred and/or reoccurred when previous decision-making addressed only symptoms (and not causes) of problems and failed to address long-term equipment reliability issues. These types of events, coupled with feedback from external assessment agencies, prompted additional leadership team analysis and reflection. The team determined that poor decision-making was undermining equipment safety margins and long-term safe plant operation. Multiple decision-making weaknesses were noted including weaknesses in plant staff technical and/or operating knowledge and skills, the inadequate or incomplete execution of planned improvement actions, and a failure to adequately assess the input from all people and sources.

Problem:

The plant needed a comprehensive, systematic decision-making tool to help guide plant decision-making and improve plant safety margins, equipment reliability and long-term plant performance.

Solution:

Plant management developed and implemented a plant operational decision-making (ODM) model based on WANO guidance.

Description:

“WANO Guideline, GL 2002-01, Principles for Effective Operational Decision-making” provides a series of principles and attributes for building a culture in which the management can systematically and rigorously help guide operational decision-making in efforts to ensure safe and reliable plant operation. This model strengthened the quality and completeness of decisions made and helped ensure the execution of effective follow-up action during decision implementation. Plant staff developed a management procedure entitled “Plant Operational Decision-Making” to describe the principles, set management expectations, and provide guidelines for use of ODM.

ODM is applicable during degraded plant conditions that result in reductions of immediate or longer term equipment and plant safety margins. ODM is also invoked in response to discrete plant occurrences that pose threats to operational safety and reliability. Post transients and shutdowns, an ODM guide helps operator decision-making to ensure that plant event causes are understood, effectively resolved or addressed, and that safe plant recovery can begin.

In 2014, the plant completed the formal implementation of the ODM. The implementation included the completion of ODM training, the release of the management procedure for use, and formal authorization and direction for the practical application of the ODM. To date, numerous long-term defects with potential safety consequences have been eliminated successfully using the ODM. Several important examples of ODM application at the plant are described as follows:

1. In 2015, the bottom of the condenser heat sink was making an abnormal noise. Using the ODM, a phase change within the condensate of the condenser was identified. Temporary

measures were made to address the condition and eliminate the abnormal noise. More importantly, additional plant monitoring, coupled with a complete plant system history review, prompted further analysis and identified that the plant's cancellation of an earlier modification to the turbine gland steam cooler was inappropriate. The initial design was restored to correct the problem long term. The extent of condition review prompted the correction of this issue on upcoming units 2 through 6.

2. The secondary impeller of the ASG turbine driven pump failed in 2017. On the strength of the ODM, both a short-term scheme and a final solution were fully developed. In this circumstance, the impact of naysayer opinions was of significant benefit during the decision-making process. Additional actions and improvements in planned actions were identified. These actions included the conduct of a safety assessment of the current unit status. Additional condition monitoring requirements were implemented and the procurement, preparation and installation of contingency, emergency spare parts were completed. In this way, the safety of the power plant was furthered strengthened.

3. In 2017, a significant threat to the reliable supply of mechanical seal water to a CRF pump was identified. The ODM process yielded a series of short-term corrective measures and contingency plans to ensure adequate mechanical seal water supply to the CRF pump. Additional pump parameter condition monitoring was put in place and that output was provided to the manufacturer for performance analysis. Performance analysis prompted the consideration of an alternative mechanical seal model design change to improve operational reliability of the CRF pump, and the conduct of a feasibility study for the elimination of a potentially, unnecessary pump trip at mechanical seal water low pressure.

4. In 2018, turbine stress protection was initiated during rapid load reduction of the turbine (i.e. turbine runback speed was controlled and limited to less than 50 MW/sec during the emergency runback of the unit). Subsequent transient analysis prompted the conduct of an ODM. Event data was collected and shared with external technical support (manufacturers). The review and analysis resulted in adjustments to the turbine stress protection system to provide greater protection to the turbine and associated plant equipment during a broader range of service and transient conditions. Turbine protection and operational risk was dramatically improved.

5. The MV contactor V4 power boards for units 1-4 were replaced in 2018. An ODM was conducted to review the failure of these power boards. The ODM prompted a comprehensive equipment analysis of theses failures which yielded multiple concerns. The need to replace a large scope of plant power boards was determined, and a specific treatment scheme was developed and executed using a graded approach by safety and reliability priority. Additionally, a planned and timely corrective action effectiveness review identified defects in newly acquired V5 spare parts.

6. Inadequate redundancy in the design features of installed air compressors was identified in 2019. Both a short-term provisional scheme and a final problem solution were developed and prepared using the ODM guidance and tools. In the on-site implementation of the provisional scheme, new problems were discovered. Additional review meetings using the ODM were conducted to discuss, modify and improve the scheme for enhancing safe and reliable plant implementation. The long-term design change was developed, approved and implemented to restore intended equipment redundancy. This redundancy was challenged during a simultaneous two-unit outage during 2019. An installed temporary air compressor - a measure developed via the ODM – successfully maintained needed plant support.

Conclusion:

The plant's ODM process was developed and implemented rigorously. The ODM guideline featured the following important attributes:

- Required the capture and documentation of the basis for plant operational decision-making. Decision-making documents are collected and archived to ensure traceability. This is done as stipulated explicitly in the ODM procedure.
- Highlighted the need to listen carefully to all and varied opinions, especially the opinions from naysayers. Moreover, the naysayer principle has been embraced in other organizational decision-making processes. The opinions of naysayers prompt more thorough and thoughtful analysis of the causal factors of plant and organizational problems and the development of more complete and robust improvement actions to assure safety and enhance performance. Additionally, the plant ODM process during emergency outage recovery requires that any and all objections to plant recovery be recorded and the basis for associated actions taken be clarified.
- Acknowledged the benefit of closely monitoring the actions taken to implement decisions made. A variety of means, to include the creation and use of visual tracking indicators, the use of special plans, intrusive field supervision at all levels, and follow-up action review meetings, are used to ensure the effective implementation of planned improvement actions and get feedback on the quality and impact of decisions made and associated actions taken.

The development and implementation of a comprehensive and systematic approach to operational decision-making proved invaluable in protecting and strengthening equipment safety margins and improving near and long-term plant performance. The plant management staff learned how to use the techniques effectively and came to appreciate the use and benefits of doing so.

G. Conducting Operational Readiness Exercises (OREs)

Background:

This project consists of four APR-1400 units which are scheduled for sequential construction and startup beginning in 2020. Safety and quality are communicated as the project's overriding priorities.

In preparation for a safe initial startup of the units, the plant desired to assess the organization's level of operational readiness. A methodology was needed to challenge the readiness for plant operation of all critical processes, programs, procedures, plant and people. The concept of operational readiness exercises (OREs) was created. The methodology was designed to stress test the organization and its use of an integrated suite of processes, programs and procedures within the plant.

An ORE is an exercise to evaluate whether personnel can use the existing suite of processes, programs, procedures and supporting plant equipment in an integrated manner to effectively execute plant activities and respond to conditions and situations that would typically be experienced in an operating nuclear power plant and organization. This concept ensures that staff have been exercised under simulated conditions to achieve planned outcomes.

ORE's were designed to answer the questions, "Do our processes, programs, procedures and equipment work?" and "Can our people effectively use them?" An organization would need to perform relatively simple tasks as well as be able to work through more complex scenarios. The plant used the concept of ORE to create operational capability and grow organizational proficiency.

The approach taken was to use three levels of OREs to test operational readiness. The three levels are:

1. Task Level (least complex)
2. Objective Level
3. Scenario Level (most complex)

OREs are categorized into three levels of complexity as shown in figure 1. The simplest being task level followed by objective level. Scenario level is the most complex.

Fig. 1 Operational Readiness Exercise (ORE) Complexity

Source: Nawah Energy Company

Tasks - A task level ORE forms the lowest level of exercise and utilizes demonstration criteria against which it is assessed. Refer to figure 2 below that explains the components (i.e. building blocks) of a task level ORE.

- Objectives – An objective level ORE describes the activity that must be demonstrated which includes multiple tasks. This is an intermediate-level exercise. Refer to figure 3 below.
- Scenarios – The highest level of ORE consisting of multiple objectives and includes greater cross-functional integration and complexity. Such exercise can span from a few hours to a few days in duration. Refer to figure 3 below.

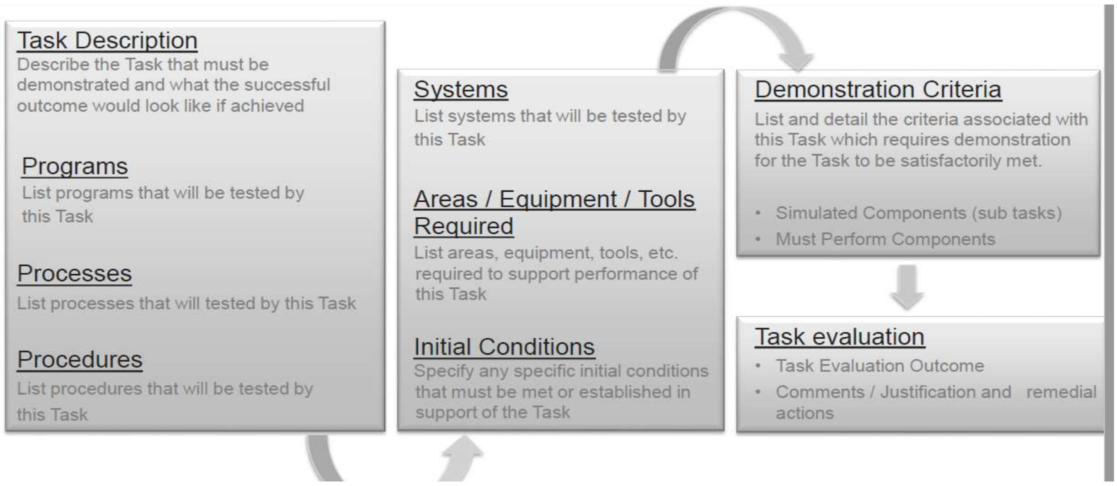


Fig. 2 Components of a Task Level ORE

Source: Nawah Energy Company

Examples of OREs

Task Level ORE

- Raise and implement an outage permit to work.

Objective Level ORE

- Respond to a sulfuric acid chemical spill on the 73’ elevation of turbine generator building.

Scenario Level ORE

- Perform a scenario from notification of failed equipment (functional failure) through to work screening (priority 2), scheduling to support work, creation of a work package, conduct of the pre-job brief, actual or simulated conduct of component work task (using work time compression as necessary), post-job debriefing and work package closure.

Modular Approach to OREs

OREs were conceived and designed so that multiple task level OREs can be combined (in a modular fashion) to develop an objective level ORE. In turn, multiple objective level OREs can be combined to develop a scenario level ORE (Refer to figure 3 below). Using tasks as building blocks allows flexibility of use and creates the ability to couple tasks and objectives to grow scenario level complexity over time. Additionally, in the event of an unsatisfactory objective or scenario level exercise, this approach allows a specific task failure(s) to be identified and then specifically exercised again. This prevents the need to repeat an entire objective or scenario level ORE if unnecessary.

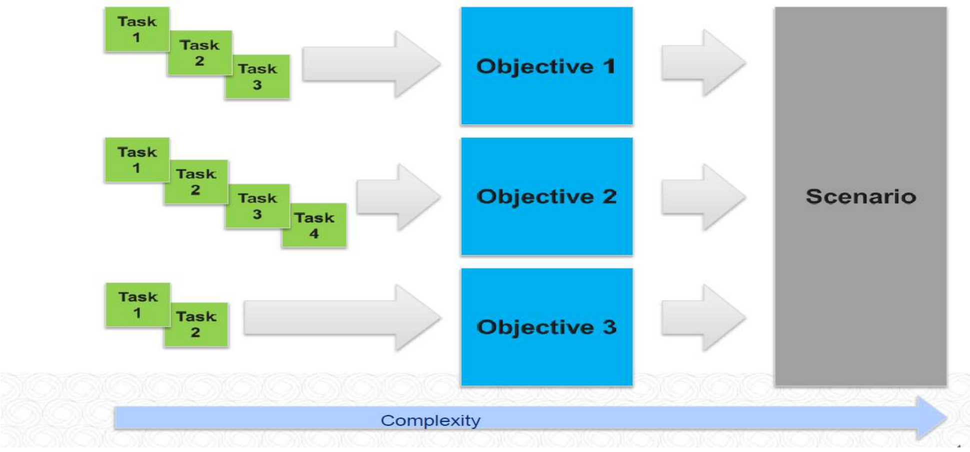


Fig. 3 Modular Approach to OREs

Source: Nawah Energy Company

ORE Development:

The scope, nature and number of the OREs are determined by the respective functional leaders based on a combination of must demonstrate capability and areas they believe that weaknesses may exist. The proposed scope is approved by the applicable executive.

When developing task, objective and scenario level OREs, performance criteria must be developed to allow the effective planning, execution and evaluation of an ORE.

ORE Execution and Evaluation

An ORE execution plan is developed for each task, objective or scenario. The plan describes how an ORE will be conducted. The execution plan will also specify the demonstration success criteria to be used for evaluation of the ORE.

The followings are typical precautionary considerations made before executing the planned OREs:

- Exercises shall minimize interference with plant operations, maintenance and construction activities whenever possible.
- Exercise activities shall be suspended in the event of an emergency or as required by a controller.
- Exercises shall maintain the safety of employees and plant.
- The applicable operation shift manager will review and approve the implementation of exercises that will be conducted in the plant.

OREs are executed by controllers (staff designated to administer the exercise) and evaluated by an evaluator (staff designated to evaluate if exercise criteria were satisfactorily met). An evaluation report is written that describes and grades the outcome of the ORE and recommends remedial actions when necessary.

Upon completion of the exercise, the evaluator will communicate the results to the responsible executive who will decide what actions are required (if any), and if the exercise (or part of the exercise) must be repeated.

An exercise is considered complete when the described activities are completed and actions, if any, required to be taken for operational readiness have been identified and documented.

Exercise records (data records, logs, etc.), used by participants to transmit or record information is collected by the evaluator at the end of an exercise.

Oversight of OREs

A cross-functional working group (ORE Oversight Committee) was established to ensure proper oversight is given to the development, execution and evaluation of each task, objective and scenario level ORE. The ORE Oversight Committee, through individual and collective knowledge and experience, provided the plant organization an independent view of operational readiness.

Key Benefits

OREs can be implemented from the point at which the operator organization takes control of the plant from the constructor through to commercial operations. The key benefits of OREs are:

- Credible, documented evidence that the operator has the functional capability and operational proficiency to safely operate the plant under normal and abnormal operating conditions.
- Early identification of potential gaps to operational readiness to allow for timely corrective actions where necessary.
- Independent assurance that the operator is ready to invite external assessment of operational readiness (e.g. IAEA and WANO).
- A means of building regulator confidence in support of plant license receipt.

Conclusion:

OREs can build leadership team confidence in your organization’s ability to conduct safe and efficient plant operations.

H. Implementing Chemistry Best Practices

Opportunity A: Leverage the benefit of EPRI Water Chemistry Guidelines

Description: This new plant chemistry department developed a secondary water chemistry strategic plan as required by the EPRI secondary water chemistry guidelines. This included a requirement for doing (ETA) optimization testing after the completion of power ascension testing (PAT) to determine the optimum concentration for minimizing erosion corrosion and ionic impurities. The plant sought consultant support to support the development and execution of such testing, but was unsuccessful in identifying anyone with suitable expertise willing to travel to the plant for the time required.

In 2018, the plant chemistry department began discussions with EPRI to see if it had the capability to provide the support the station needed. In early 2019, EPRI completed work on their secondary plant computer model and agreed to provide plant support. A formal agreement was reached, and procurement was completed.

EPRI received the plant's secondary system design information, modelled system flow and conditions, and created an ETA test plan to evaluate corrosion and condensate polisher performance at varying ETA concentrations. This information helped establish chemistry performance targets for the APR-1400 design.

Recommendation: Consider the use of EPRI relationships and expertise to support plant activities like that described above.

Opportunity B: Implementation of Reactor Coolant System (RCS) Zinc Injection for New PWR Units

Description: The APR-1400-unit original design did not include injection of zinc into the RCS to minimize the production of primary system irradiated, corrosion by-products and, in doing so, reduce plant dose levels. The plant's chemistry department directed a construction change request (CCR) to add RCS zinc injection for all plant units.

At the time of approval of the CCR, there was insufficient time for zinc skid design, fabrication and installation before Hot Function Testing (HFTs) for units 1 and 2. Notwithstanding, the CCR process moved ahead, with the target of implementing zinc injection in time for HFTs for units 3 and 4, and at the earliest opportunity for units 1 and 2. A unit schedule delay created an opportunity to implement zinc injection during the startup of units 1 and 2. These projects were incorporated into the operational readiness schedule.

Zinc injection design and skid fabrication was accelerated for units 1 and 2 and scheduled to occur prior to initial plant startup and power ascension testing (PAT). Additionally, zinc injection implementation proceeded as scheduled on units 3 and 4 to occur during the first HFT for each unit. As such, the plant will have the globally unique opportunity to observe the direct impact on radiation dose rates by RCS zinc implementation on four identical units - two with a zinc passivation layer established during the first HFT and two with a zinc passivation layer established prior to startup and PAT.

Recommendation: Consider the addition of RCS zinc injection during new unit startup post construction to improve plant dose rates for the operation of the plant's life. Do this during the plant's first HFT, if possible, to optimize the formation of a zinc-rich initial corrosion film.

I. Achieving Standards of Excellence in New Plant Material Condition

Background:

Many new build plants suffer from low quality installation of equipment during plant construction. Poor quality issues include 1) safety-related equipment in direct contact with plant structures such as floor grating and concrete penetrations, 2) less than adequate support for safety-related piping, 3) inadequate equipment fastener practices, and 4) inadequate safety-related cable installation. If present during the harsh temperature, humidity, seismic and radiation conditions that can occur during accident conditions, the quality issues cited can result in safety system equipment unavailability. During normal operating conditions, normal plant vibration can accelerate structural damage to safety-related equipment and result in premature failure. By way of example, one industry unit in its first operating cycle experienced a small-bore pipe failure and subsequent loss of reactor coolant due to pipe abrasion with the sharp edges of nearby floor grating.

Good Practices:

This new plant project placed significant emphasis on high quality equipment installation during construction and commissioning. Plant walk-downs, issue identification, and effective follow-up actions by owner personnel during the construction period have raised equipment installation standards.

As a result, no adverse conditions on safety-related systems have been noted during WANO visits and observations. Positive observations included:

- All safety-related system components have adequate clearance to adjacent equipment and plant structures.
- Cables are well routed within their cable trays - no cable tray is overloaded; no cable surface is exposed to sharp edges.
- Fastening bolts and nuts are well engaged with proper thread length.
- Pipe supports, snubbers and dampers are properly installed to minimise flow induced vibration.

J. Leveraging Continuous Improvement across Multiple Units

Background:

This project is a multi-unit nuclear site with six 1000-Megawatt PWR reactors.

Challenge:

The site targeted performance improvement in all areas of safety, quality, cost and schedule for the construction, commissioning and operation of each subsequent unit. The organization desired to improve its safety record, strengthen its foundation of governance, grow employee knowledge and skill, and improve plant engineering quality while achieving ever increasing levels of efficiency.

Solution:

The organization first adopted, communicated and pursued a principle expressed by "Safety First, Quality First and the Pursuit of Excellence." It then developed and implemented a rigorous model for continuous and sustainable performance improvement. The model was designed to leverage the operating experience (OE) and the associated lessons learned from both internal and external industry sources. The model of continuous performance improvement had five key elements as described below:

Description:

1. Rigorously identify, capture and use the operating experience from one unit to the next.

   A formal initiative was undertaken to establish and implement an approach to identify, capture and use OE from one unit to the next during all phases of construction, commissioning and operation. A project team was assembled. An approach was implemented jointly with the plant staff and the EPC contractor. A formal closed-loop system was developed that captured the integrated experience from the construction, commissioning and operating experience of both internal and external nuclear and non-nuclear projects. This system provided an opportunity to share experiences, define improvement actions, and track implementation actions. A plant experience feedback committee was formed that included senior management from both the plant operating staff and EPC personnel. Efforts were made to raise issues as early as possible to allow adequate time for improvement action development and implementation. Issue resolution addressed significant technical issues and organizational performance issues that improved safety and efficiency. Early improvement action also allowed application to multiple units which amplified the benefits of each initiative. Senior leaders actively enforced and verified the implementation of all planned improvement actions.

   Once the six units were placed in service, the plant staff continued to embellish the OE system over time and have broadened the scope to include daily work, outage management and integrated plant/EPC contract management experience as well as lessons learned.

2. Use of Peer Groups (PGs)

   The corporation designed and implemented 21 PGs in the following functional areas: nuclear safety and licensing, emergency preparedness, routine operations, operations management, training, OE, schedule management, chemical environment, outage management, spare parts management, operations preparation, equipment management, engineering modifications, technical management, nuclear fuel management, document management, nuclear safety independent oversight, fire and industrial safety, anti-terrorism security, radiation protection, and occupational health and quality assurance. PGs established a foundation of standardized governance and performance measures for each functional area. Both were developed based on industry benchmarks.

The PGs routinely executed a process of plant performance oversight. Each peer group compared each unit's performance to industry levels of excellence. Subsequent analysis allowed for the development and implementation of improvement actions, strategic initiatives and plant projects in pursuit of targeted performance gains. By doing this, the PGs identified and addressed issues that existed across the fleet of plants and took action to strengthen governing processes, programs and techniques.

Additionally, the PGs for each functional area rigorously compared the performance of each unit to one another. They compared field observations and performance indicators for each plant to detect performance deviations and gaps between plants. By doing this, the PGs identified and addressed issues at individual units.

Finally, the PGs encouraged plant functional area staff to help in the definition of standards, development of improvement actions and solutions, and the identification and implementation of good practices from within the industry. The PGs actively promote sharing knowledge and experience across the organization.

3. The use of careful and deliberate succession planning

   Organizational knowledge is captured in the governance standards, plant software systems, and, most importantly, in the minds of employees. The experiences and developed expertise of employees must be carefully cultivated over time. Careful and deliberate succession planning has helped organization grow the number of employees with significant experience and expertise and thus set the stage for later plant performance gains.

   The site established a sound career development system for all employees. The plant offered two career development paths – one for management and one for technical professionals. A mechanism was created that could allow employees to move from one to another based on gained knowledge and skills and demonstrated behaviours. A reserve management concept was developed and implemented to promote a virtuous cycle of management succession. The development of employee competencies included self-study, classroom training, on-the-job training, and developmental assignments under close supervision. The plant also developed a knowledge management platform system to support employee sharing of knowledge and experience.

4. A focused approach to managing key issues during commissioning

   During the commissioning of Units 1-6, the commissioning department set up a task force on foreign material exclusion (FME). The objectives of the task force were to protect the integrity of system components and systems and promote the quality execution of the FME program in the field. The task force conducted independent field observations of the implementation of the FME program. The observers provided feedback that contributed to the improvements in the FME program and its execution. Improvements included optimizations in system flushing schemes and post-flushing foreign material identification. Special technical teams were set up to address findings and technical issues arising from the execution of the FME process during commissioning. The commissioning lead took a hands-on role in ensuring FME program implementation, execution and problem resolution.

5. Effective response to PSUR areas for improvement (AFI)

Since the first PSUR of Unit 1 in 2013, WANO has conducted PSURs annually prior to the start of each plant's fuel load and subsequent operation. The scope of these reviews and critical assessments included the performance areas of operations, maintenance, technical support, chemistry, radiation protection, emergency preparedness, fire protection, training, and leadership and organizational effectiveness. The AFIs identified during a new unit's PSUR generated actions that were used to strengthen the governance applicable to all of the plants and to improve the performance of each subsequent unit. The aforementioned peer groups facilitated this process. Detailed action plans were developed and implemented to promote continuous improvement of plant operation across the six units.

As an example: During the WANO PSUR of Unit 4, the review team raised AFIs in the implementation standards for building and facility management. This finding included issues with inadequate fire barriers and fire protection systems. A corrective action was generated. A higher building and facility standard typically applicable to the later phase of commercial operation was implemented earlier in the construction and commissioning process for units 5 and 6. This approach was also incorporated into the building management schedule for all subsequent units across the corporate organization. Thus, the AFI action was institutionalized.

Additionally, the plant criteria (and the fleet standard) was upgraded to require fire protection system availability and the adequacy of fire barriers as a prerequisite for the feeding of oil and subsequent startup of key plant equipment and systems. The fire protection availability standard was also incorporated into the plant's indicators for the assessment of contractor performance in safety, quality and the environment. The actions taken from this single AFI improved building standards and enhanced fire protection during the construction of all future units.

Conclusion:

The organization created and implemented an effective model of continuous improvement to improve its operation and sustain these improvements over time. The five good practices outlined above have been used to create significant performance gains during the construction, commissioning and operation of each sequential unit at the site. Improvement actions taken to address plant operating experience positively impacted performance in all areas of safety, quality, schedule and cost.

Proof of such performance gains are numerous. For example, in 2018, the plant was awarded the corporations highest honour for the fourth consecutive year. This award is based primarily on the achievement of outstanding plant performance as measured by the WANO indicators. Additional awards included individual unit performance awards for units 1 and 2 and the nation's highest Nuclear Energy Project Quality Award for units 3 and 4 in 2019. Other notable achievements included a unit construction duration record for the reactor series of 51.9 months and a duration record from the start of cold functional testing to commercial operation of 9 months on unit 6. The operating performance records of each of the six units and the awards received in acknowledgement of such are indicative of the effective use of plant and industry operating experience and the rigorous implementation of associated lessons learned.

K. Conducting Transient-Free Plant Startup and Power Ascension Testing

Background:

This project is a multi-unit nuclear site with six 1000-Megawatt PWRs. Units 5 and 6 were the company's first efforts to construct, commission and operate a new advanced reactor design.

Problem:

With the successful completion of units 1 through 4, expectations were high for the safe and quality completion of units 5 and 6. But, first of a kind construction, commissioning and operation of the newly designed PWR would introduce new and different risks to successful project completion and unit operation. New challenges included the introduction of 31 new design safety improvements and the introduction of a domestically designed, digital control system (DCS) platform. In addition, a new nuclear island installation contractor would be employed for the project. Each of these new challenges posed a risk to successful project completion and subsequent safe plant operation. Nonetheless, the desire for transient-free startup and testing of units 5 and 6 and subsequent event-free operation of the units remained unchanged.

Solution:

Consistent with units 1 through 4, the organization first adopted, communicated and pursued a principle expressed by "Safety First, Quality First and the Pursuit of Excellence."

Next, it used a previously developed and implemented model for continuous and sustainable performance improvement. This model was used to leverage the operating experience (OE) from units 1 through 4 during the construction, commissioning and operation of units 5 and 6. (See roadmap success story J in Appendix 5)

In addition, a startup command office (SCO) was established to focus the organization's attention on the safe and transient-free startup and testing of units 5 and 6. The SCO orchestrated the use of a number of forward-looking measures taken to raise the quality of preparation and address the unique risks introduced during the startup and testing of units 5 and 6. These forward-looking measures are described in the following section.

Description:

An early and comprehensive assessment of the new technology, along with the new project risks to be introduced, was conducted. As a result, the following measures were implemented and orchestrated by the SCO in advance of project completion and unit startup and testing:

1. A joint project team was formed between the operating company and all EPC contractors. The team focused on the company principle of "Safety First, Quality First and the Pursuit of Excellence." The SOC provided oversight of team activities. Key focus areas included the receipt and storage of new fuel, plant housekeeping, foreign material exclusion, and the safe and quality conduct of critical work tasks.

2. A model for continuous improvement was implemented in units 5 and 6. The SCO carefully reviewed and confirmed that the lessons learned from units 1 through 4 were included within the unit 5 and 6 project schedules, processes, programs, performance standards and associated training and briefing materials. Additional OE and lessons learned from units 5 and 6 were captured daily. (See roadmap success story J in Appendix 5)

3. In preparation for fuel load, the SCO directed special focus on two key activities: the rigorous turnover of quality plant systems and the associated close out of punch list items (i.e. equipment quality issues and defects). A regimen of daily meetings was held to monitor schedule progress and direct timely corrective actions for these activities. The status of punch list items was reviewed each morning; the status of system turnover was reviewed each evening.

4. Indications of potential technical issues and/or concerns were proactively sought. An independent technical analysis of technical issues and concerns, or pre-diagnosis, was conducted to evaluate potential causes and consider either corrective or contingency actions. The satisfactory completion of planned corrective and contingency actions was logically tied to the final successful turnover of plant systems.

5. The pre-fuel load schedule employed a system of nodes. Each node was a collection of various plant and system inspection points. A task force was established to conduct these in-depth field inspections. The task force was responsible for the identification or all safety and quality issues. Once identified, all defects were screened by a multidisciplinary team to identify those defects requiring special focus and attention. Some 683 of over 20,000 defects identified were screened as high priority.

6. The resolution of high-priority defects was required prior to successful system turnover. The balance of plant component and system defects were completed and independently verified complete prior to fuel load. Some 14,000+ punch list items were satisfactorily completed prior to fuel load. Some inconsequential punch lists items were scheduled and tracked to completion after fuel load.

7. Special inspection teams were assembled, and special effort was expended to inspect and assess the installation of the 31 new plant design features prior to testing. Follow-on efforts were made to carefully monitor, manage and control the risks of these new improvements when tested.

8. The post fuel load startup schedule was created using the mode changes specified by the plant's technical specifications. System status and testing criteria, along with the completion of any newly identified defects, were logically tied to these scheduled mode changes. Senior management led specially formed issue resolution teams to correct newly identified defects of significance that were tied to plant mode changes. The progress of these defect resolution teams was monitored by the SCO each day.

9. A system of routine preventive maintenance tasks was developed, scheduled and executed to maintain plant equipment reliability throughout plant startup and testing schedule.

10. Preparation for major plant transient testing included the collection and review of testing data from units 1 through 4. Test procedures and plans were revised using past OE. Testing prerequisites were identified and scheduled. Simulator test scenarios were developed using the data and experiences form previous unit tests. These scenarios were used to conduct just-in-time simulator training with the plant control room crews and key testing personnel. These scenarios included the introduction of faults to prepare the crews for probable occurrences. Human performance techniques to include detailed pre-job briefs were conducted in preparation for each of the evolutions scheduled during plant startup and testing.

Conclusion

The site employed a rigorous ten dimension approach to the startup and testing of units 5 and 6 with numerous FOAK design features. The site coupled this approach with the personal devotion and professional discipline of the plant staff to deliver a transient-free startup of units 5 and 6. The results achieved were outstanding and largely unprecedented.

Appendix 6: Master Reference List

No	Source Org.	Document Title	Link	Publicly Available?	Project evaluation	Project Commercial Contracting	Plant Construction	Plant Commissioning	Plant Commercial Operation
1	EPRI	Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document, Revision 13	Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document, Revision 13	No	Yes	Yes	Yes	Yes	Yes
2	EPRI	Advanced Nuclear Technology: Advanced Light Water Reactors Utility Requirements Document Small Modular Reactors Inclusion Summary	Advanced Nuclear Technology: Advanced Light Water Reactors Utility Requirements Document Small Modular Reactors Inclusion Summary	No	Yes	Yes	No	No	No
3	EPRI	Advanced Nuclear Technology: Demonstration of the Applicability of Risk-Informed In-Service Inspection to the New Build Fleet	Advanced Nuclear Technology: Demonstration of the Applicability of Risk-Informed In-Service Inspection to the New Build Fleet	No	No	Yes	Yes	Yes	Yes
4	EPRI	Advanced Nuclear Technology: Guidance for Cybersecurity During New Nuclear Plant Construction	Advanced Nuclear Technology: Guidance for Cybersecurity During New Nuclear Plant Construction	No	No	Yes	Yes	Yes	Yes

5	EPRI	Advanced Nuclear Technology: New Nuclear Power Plant Information Turnover Guide (Revision 1)	Advanced Nuclear Technology: New Nuclear Power Plant Information Turnover Guide (Revision 1)	No	No	Yes	Yes	Yes	Yes
6	EPRI	Cybersecurity Procurement Methodology	Cybersecurity Procurement Methodology	No	No	Yes	Yes	Yes	Yes
7	EPRI	Guidelines for Fabrication and Assembly of Alloy 690 Components in PWR Primary Systems	Guidelines for Fabrication and Assembly of Alloy 690 Components in PWR Primary Systems	No	Yes	Yes	Yes	No	No
8	EPRI	Methodology for Risk-informed Procurement for New Plant Deployment	Methodology for Risk-informed Procurement for New Plant Deployment	No	Yes	Yes	Yes	Yes	Yes
9	EPRI	Program on Technology Innovation: EPRI Workshop on Process Hazard Analysis to Probabilistic Risk Assessment for Advanced Reactors Proceedings: Vanderbilt University, Nashville, TN, July 18-19, 2017	Program on Technology Innovation: EPRI Workshop on Process Hazard Analysis to Probabilistic Risk Assessment for Advanced Reactors Proceedings: Vanderbilt University, Nashville, TN, July 18-19, 2017	No	No	Yes	No	No	No
10	EPRI	Program on Technology Innovation: Expanding the Concept of Flexibility for Advanced Reactors, Refined Criteria, a Proposed Technology Readiness Scale, and Time-Dependent	Program on Technology Innovation: Expanding the Concept of Flexibility for Advanced Reactors, Refined Criteria, a Proposed Technology Readiness Scale, and Time-Dependent Technical Information Availability	No	Yes	Yes	Yes	Yes	Yes

		Technical Information Availability							
11	EPRI	Program on Technology Innovation: Government and Industry Roles in the Research, Development, Demonstration, and Deployment of Commercial Nuclear Reactors: Historical Review and Analysis	Program on Technology Innovation: Government and Industry Roles in the Research, Development, Demonstration, and Deployment of Commercial Nuclear Reactors: Historical Review and Analysis	No	Yes	Yes	No	No	No
12	EPRI	Program on Technology Innovation: Owner-Operator Requirements Guide (ORG) for Advanced Reactors, Revision 0	Program on Technology Innovation: Owner-Operator Requirements Guide (ORG) for Advanced Reactors, Revision 0	No	Yes	Yes	Yes	Yes	Yes
13	EUCG	EUCG Standard Nuclear Performance Model	https://www.eucg.org/committees/nuclear.cfm	No	Yes	Yes	Yes	Yes	Yes
14	EUR	European Utility Requirements for LWR Nuclear Power Plants (Volume 2)	EUR Vol 2	No	Yes	Yes	Yes	Yes	Yes
15	EUR	European Utility Requirements for LWR Nuclear Power Plants (Volume 4)	EUR Vol 4	No	Yes	Yes	No	No	Yes

16	IAEA	Application of the Management System for Facilities and Activities (IAEA Safety Standards Series No. GS-G-3.1, 2006)	Application of the Management System for Facilities and Activities (IAEA Safety Standards Series No. GS-G-3.1, 2006)	Yes	Yes	Yes	Yes	Yes	Yes
17	IAEA	Arrangements for Preparedness for a Nuclear or Radiological Emergency (IAEA Safety Standards Series No. GS-G-2.1, 2007)	Arrangements for Preparedness for a Nuclear or Radiological Emergency (IAEA Safety Standards Series No. GS-G-2.1, 2007)	Yes	No	Yes	Yes	Yes	Yes
18	IAEA	Basic Safety Principles for Nuclear Power Plants (INSAG Series No. 12, 1999)	Basic Safety Principles for Nuclear Power Plants (INSAG Series No. 12, 1999)	Yes	No	Yes	Yes	Yes	Yes
19	IAEA	Building Capacity for Nuclear Security, Implementing Guide, IAEA Nuclear Security Series No. 31-G, 2018	Building Capacity for Nuclear Security, Implementing Guide, IAEA Nuclear Security Series No. 31-G, 2018	Yes	No	Yes	Yes	Yes	Yes
20	IAEA	Classification of Radioactive Waste (IAEA Safety Standards Series No. GSG-1, 2009)	Classification of Radioactive Waste (IAEA Safety Standards Series No. GSG-1, 2009)	Yes	No	Yes	Yes	Yes	Yes
21	IAEA	Commissioning Guidelines for Nuclear Power Plants (IAEA NE Series No. NP-T-2.10, 2018) (Mainly for Phase 3)	Commissioning Guidelines for Nuclear Power Plants (IAEA NE Series No. NP-T-2.10, 2018) (Mainly for Phase 3)	Yes	No	Yes	No	Yes	Yes

22	IAEA	Communication and Consultation with Interested Parties by the Regulatory Body (IAEA Safety Standards Series No. GSG-6, 2017)	Communication and Consultation with Interested Parties by the Regulatory Body (IAEA Safety Standards Series No. GSG-6, 2017)	Yes	Yes	Yes	Yes	Yes	Yes
23	IAEA	Comprehensive Safeguards Agreement between the State and the IAEA (INFCIRC/153, 1972)	Comprehensive Safeguards Agreement between the State and the IAEA (INFCIRC/153, 1972)	Yes	Yes	Yes	Yes	Yes	Yes
24	IAEA	Construction Management (IAEA E-learning Module)	Construction Management (IAEA E-learning Module)	Yes	No	Yes	Yes	No	No
25	IAEA	Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (INFCIRC/336, 1986)	Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (INFCIRC/336, 1986)	Yes					
26	IAEA	Convention on Early Notification of a Nuclear Accident (INFCIRC/335, 1986)	Convention on Early Notification of a Nuclear Accident (INFCIRC/335, 1986)	Yes					
27	IAEA	Convention on Nuclear Safety (INFCIRC/449, 1994)	Convention on Nuclear Safety (INFCIRC/449, 1994)	Yes					
28	IAEA	Convention on the Physical Protection of Nuclear Material (INFCIRC/274, 1979)	Convention on the Physical Protection of Nuclear Material (INFCIRC/274, 1979)	Yes					

29	IAEA	Cost Considerations and Financing Mechanisms for the Disposal of Low and Intermediate Level Radioactive Waste (IAEA TECDOC No. 1552, 2007)	Cost Considerations and Financing Mechanisms for the Disposal of Low and Intermediate Level Radioactive Waste (IAEA TECDOC No. 1552, 2007)	Yes	Yes	Yes	No	No	No
30	IAEA	Culture for Safety (IAEA E-learning Module)	Culture for Safety (IAEA E-learning Module)	Yes	No	Yes	Yes	Yes	Yes
31	IAEA	Decommissioning of Facilities General Safety Requirements, No. GSR Part 6	https://www.iaea.org/publications/10676/decommissioning-of-facilities	Yes	Yes	Yes	Yes	Yes	Yes
32	IAEA	Developing a Human Resource Strategy (IAEA E-learning Module)	Developing a Human Resource Strategy (IAEA E-learning Module)	Yes	No	Yes	Yes	Yes	Yes
33	IAEA	Development and Implementation of a Process Based Management System (IAEA NE Series No. NG-T-1.3, 2015)	Development and Implementation of a Process Based Management System (IAEA NE Series No. NG-T-1.3, 2015)	Yes	No	Yes	Yes	Yes	Yes
34	IAEA	Development, Use and Maintenance of the Design Basis Threat (IAEA Nuclear Security Series No. 10, 2009)	Development, Use and Maintenance of the Design Basis Threat (IAEA Nuclear Security Series No. 10, 2009)	Yes	No	Yes	Yes	Yes	Yes
35	IAEA	Disposal Approaches for Long Lived Low and Intermediate Level	Disposal Approaches for Long Lived Low and Intermediate Level Radioactive Waste (IAEA NE Series No. NW-T-1.20, 2010)	Yes	Yes	Yes	No	No	No

		Radioactive Waste (IAEA NE Series No. NW-T-1.20, 2010)							
36	IAEA	Disposal of Radioactive Waste Specific Safety Requirements, No. SSR-5	https://www.iaea.org/publications/8420/disposal-of-radioactive-waste	Yes	Yes	Yes	Yes	Yes	Yes
37	IAEA	Electric Grid Reliability and Interface with Nuclear Power Plants (IAEA NE Series No. NG-T-3.8, 2012)	Electric Grid Reliability and Interface with Nuclear Power Plants (IAEA NE Series No. NG-T-3.8, 2012)	Yes	Yes	Yes	No	No	No
38	IAEA	Emergency Preparedness and Response (IAEA E-learning Module)	Emergency Preparedness and Response (IAEA E-learning Module)	Yes	No	Yes	Yes	Yes	Yes
39	IAEA	Establishing the Nuclear Security Infrastructure for a Nuclear Power Programme (IAEA Nuclear Security Series No. 19, 2013)	Establishing the Nuclear Security Infrastructure for a Nuclear Power Programme (IAEA Nuclear Security Series No. 19, 2013)	Yes					
40	IAEA	Establishing the Safety Infrastructure for a Nuclear Power Programme (IAEA Safety Standards Series No. SSG-16, 2012)	Establishing the Safety Infrastructure for a Nuclear Power Programme (IAEA Safety Standards Series No. SSG-16, 2012)	Yes	No	Yes	Yes	Yes	Yes
41	IAEA	Feasibility Study (IAEA E-learning Module)	Feasibility Study (IAEA E-learning Module)	Yes	Yes	No	No	No	No

42	IAEA	Financing of New Nuclear Power Plants (IAEA NE Series No. NG-T-4.2, 2008)	Financing of New Nuclear Power Plants (IAEA NE Series No. NG-T-4.2, 2008)	Yes	Yes	Yes	No	No	No
43	IAEA	Functions and Processes of the Regulatory Body for Safety (IAEA Safety Standards Series No. GSG-13, 2018)	Functions and Processes of the Regulatory Body for Safety (IAEA Safety Standards Series No. GSG-13, 2018)	Yes					
44	IAEA	Fundamental Safety Principles (IAEA Safety Standards Series No. SF-1, 2006)	Fundamental Safety Principles (IAEA Safety Standards Series No. SF-1, 2006)	Yes	Yes	Yes	Yes	Yes	Yes
45	IAEA	Fundamental Safety Principles, Safety Fundamentals, No. SF-1	https://www.iaea.org/publications/7592/fundamental-safety-principles	Yes	Yes	Yes	Yes	Yes	Yes
46	IAEA	Governmental, Legal and Regulatory Framework for Safety (IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), 2016)	Governmental, Legal and Regulatory Framework for Safety (IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), 2016)	Yes					
47	IAEA	Governmental, Legal and Regulatory Framework for Safety General Safety Requirements, No. GSR Part 1	https://www.iaea.org/publications/10883/governmental-legal-and-regulatory-framework-for-safety	Yes	Yes	Yes	Yes	Yes	Yes

48	IAEA	Guidance for States Implementing Comprehensive Safeguards Agreements and Additional Protocols (IAEA Services Series No. 21, 2012)	Guidance for States Implementing Comprehensive Safeguards Agreements and Additional Protocols (IAEA Services Series No. 21, 2012)	Yes					
49	IAEA	Handbook on Nuclear Law (2003)	Handbook on Nuclear Law (2003)	Yes	Yes	Yes	Yes	Yes	Yes
50	IAEA	Handbook on Nuclear Law: Implementing Legislation (2010)	Handbook on Nuclear Law: Implementing Legislation (2010)	Yes					
51	IAEA	IAEA Safety Glossary: 2018 Edition	https://www.iaea.org/publications/11098/iaea-safety-glossary-2018-edition	Yes	Yes	Yes	Yes	Yes	Yes
52	IAEA	Independence in Regulatory Decision-making (INSAG Series No. 17, 2003)	Independence in Regulatory Decision-making (INSAG Series No. 17, 2003)	Yes					
53	IAEA	Industrial Involvement to Support a National Nuclear Power Programme (IAEA Nuclear Energy Series No. NG-T-3.4, 2016)	Industrial Involvement to Support a National Nuclear Power Programme (IAEA Nuclear Energy Series No. NG-T-3.4, 2016)	Yes	Yes	Yes	No	No	No
54	IAEA	Introduction to Safeguards (IAEA E-learning Module)	Introduction to Safeguards (IAEA E-learning Module)	Yes	No	Yes	Yes	Yes	Yes
55	IAEA	Invitation and Evaluation of Bids for Nuclear Power	Invitation and Evaluation of Bids for Nuclear Power Plants (IAEA NE Series No. NG-T-3.9, 2011)	Yes	Yes	Yes	No	No	No

		Plants (IAEA NE Series No. NG-T-3.9, 2011)							
56	IAEA	Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management IAEA International Law Series No. 1, 2006)	Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management IAEA International Law Series No. 1, 2006)	Yes					
57	IAEA	Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention (INFCIRC/402, 1992)	Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention (INFCIRC/402, 1992)	Yes					
58	IAEA	Leadership and Management for Safety (IAEA Safety Standards Series No. GSR Part 2, 2016)	Leadership and Management for Safety (IAEA Safety Standards Series No. GSR Part 2, 2016)	Yes	No	Yes	Yes	Yes	Yes
59	IAEA	Leadership and Management for Safety General Safety Requirements, No. GSR Part 2	https://www.iaea.org/publications/11070/leadership-and-management-for-safety	Yes	Yes	Yes	Yes	Yes	Yes
60	IAEA	Legal Framework (IAEA E-learning Module)	Legal Framework (IAEA E-learning Module)	Yes	Yes	Yes	Yes	Yes	Yes
61	IAEA	Licensing Process for Nuclear Installations (IAEA Safety	Licensing Process for Nuclear Installations (IAEA Safety Standards Series No. SSG-12, 2010)	Yes	Yes	Yes	Yes	Yes	No

		Standards Series No. SSG-12, 2010)							
62	IAEA	Licensing the First Nuclear Power Plant (INSAG Series No. 26, 2012)	Licensing the First Nuclear Power Plant (INSAG Series No. 26, 2012)	Yes	Yes	No	No	No	No
63	IAEA	Management of a Nuclear Power Programme (IAEA E-learning Module)	Management of a Nuclear Power Programme (IAEA E-learning Module)	Yes					
64	IAEA	Management Systems (IAEA E-learning Module)	Management Systems (IAEA E-learning Module)	Yes	No	Yes	Yes	Yes	Yes
65	IAEA	Managing Environmental Impact Assessment for Construction and Operation in New Nuclear Power Programmes (IAEA NE Series No. NG-T-3.11, 2014)	Managing Environmental Impact Assessment for Construction and Operation in New Nuclear Power Programmes (IAEA NE Series No. NG-T-3.11, 2014)	Yes	Yes	Yes	No	No	No
66	IAEA	Managing Human Resources in the Field of Nuclear Energy (IAEA NE Series No. NG-G-2.1, 2009)	Managing Human Resources in the Field of Nuclear Energy (IAEA NE Series No. NG-G-2.1, 2009)	Yes	No	Yes	Yes	Yes	Yes
67	IAEA	Managing Regulatory Body Competence (Safety Reports Series No. 79, 2014)	Managing Regulatory Body Competence (Safety Reports Series No. 79, 2014)	Yes					
68	IAEA	Managing Siting Activities for Nuclear Power Plants (IAEA NE Series No. NG-T-3.7, 2012)	Managing Siting Activities for Nuclear Power Plants (IAEA NE Series No. NG-T-3.7, 2012)	Yes	Yes	Yes	No	No	No

69	IAEA	Managing the Financial Risk Associated with the Financing of New Nuclear Power Plant Projects (IAEA NE Series No. NG-T-4.6, 2017)	Managing the Financial Risk Associated with the Financing of New Nuclear Power Plant Projects (IAEA NE Series No. NG-T-4.6, 2017)	Yes	Yes	Yes	Yes	Yes	Yes
70	IAEA	Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards IINFCIRC/540, 1997)	Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards IINFCIRC/540, 1997)	Yes					
71	IAEA	- Milestones in the Development of a National Infrastructure for Nuclear Power	https://www.iaea.org/publications/10873/milestones-in-the-development-of-a-national-infrastructure-for-nuclear-power	Yes	Yes	Yes	Yes	Yes	Yes
72	IAEA	Nuclear Contracting Toolkit (2016)	Nuclear Contracting Toolkit (2016)	Yes	Yes	Yes	No	No	No
73	IAEA	Nuclear Power Human Resource (NPHR) Model (Brochure, 2017) Model available upon request	Nuclear Power Human Resource (NPHR) Model (Brochure, 2017) Model available upon request	Yes	Yes	Yes	Yes	Yes	Yes
74	IAEA	Nuclear Security Culture (IAEA Nuclear Security Series No. 7, 2008)	Nuclear Security Culture (IAEA Nuclear Security Series No. 7, 2008)	Yes	Yes	Yes	Yes	Yes	Yes

75	IAEA	Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5) (IAEA Nuclear Security Series No. 13, 2011)	Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5) (IAEA Nuclear Security Series No. 13, 2011)	Yes	Yes	Yes	Yes	Yes	Yes
76	IAEA	Objective and Essential Elements of a State's Nuclear Security Regime (IAEA Nuclear Security Series No. 20, 2013)	Objective and Essential Elements of a State's Nuclear Security Regime (IAEA Nuclear Security Series No. 20, 2013)	Yes					
77	IAEA	Occupational Radiation Protection (IAEA Safety Standards Series No. GSG-7, 2018)	Occupational Radiation Protection (IAEA Safety Standards Series No. GSG-7, 2018)	Yes	No	Yes	Yes	Yes	Yes
78	IAEA	Optimization of Radiation Protection in the Control of Occupational Exposure (Safety Reports Series No. 21, 2002)	Optimization of Radiation Protection in the Control of Occupational Exposure (Safety Reports Series No. 21, 2002)	Yes	No	Yes	Yes	Yes	Yes
79	IAEA	Optimizing Local Industrial Involvement (IAEA E-learning Module)	Optimizing Local Industrial Involvement (IAEA E-learning Module)	Yes	Yes	Yes	Yes	Yes	Yes
80	IAEA	Options for Management of Spent Fuel and Radioactive Waste for Countries Developing New Nuclear	Options for Management of Spent Fuel and Radioactive Waste for Countries Developing New Nuclear Power Programmes (IAEA NE Series No. NW-T-1.24, 2013)	Yes	Yes	Yes	No	No	No

		Power Programmes (IAEA NE Series No. NW-T-1.24, 2013)							
81	IAEA	Options for Management of Spent Fuel and Radioactive Waste for Countries Developing New Nuclear Power Programmes (IAEA NE Series No. NW-T-1.24, 2013)	Options for Management of Spent Fuel and Radioactive Waste for Countries Developing New Nuclear Power Programmes (IAEA NE Series No. NW-T-1.24, 2013)	Yes					
82	IAEA	Organisation, Management and Staffing of the Regulatory Body for Safety (IAEA Safety Standards Series No. GSG-12, 2018	Organisation, Management and Staffing of the Regulatory Body for Safety (IAEA Safety Standards Series No. GSG-12, 2018	Yes					
83	IAEA	Organisation, Management and Staffing of the Regulatory Body for Safety, (IAEA Safety Standards Series No. GSG-12, 2018)	Organisation, Management and Staffing of the Regulatory Body for Safety, (IAEA Safety Standards Series No. GSG-12, 2018)	Yes					
84	IAEA	Physical Protection of Nuclear Material and Nuclear Facilities (Implementation of INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 27-G, 2018	Physical Protection of Nuclear Material and Nuclear Facilities (Implementation of INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 27-G, 2018	Yes	Yes	Yes	Yes	Yes	Yes
85	IAEA	Policies and Strategies for Radioactive Waste	Policies and Strategies for Radioactive Waste Management (IAEA NE Series No. NW-G-1.1, 2009)	Yes	Yes	Yes	No	No	No

		Management (IAEA NE Series No. NW-G-1.1, 2009)							
86	IAEA	Policies and Strategies for the Decommissioning of Nuclear and Radiological Facilities (IAEA NE Series No. NW-G-2.1, 2011)	Policies and Strategies for the Decommissioning of Nuclear and Radiological Facilities (IAEA NE Series No. NW-G-2.1, 2011)	Yes	Yes	Yes	No	No	Yes
87	IAEA	Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities (IAEA Safety Standards Series No. SSG-41, 2016)	Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities (IAEA Safety Standards Series No. SSG-41, 2016)	Yes					
88	IAEA	Predisposal Management of Radioactive Waste General Safety Requirements, No. GSR Part 5	https://www.iaea.org/publications/8004/predisposal-management-of-radioactive-waste	Yes	Yes	Yes	Yes	Yes	Yes
89	IAEA	Preparation of a Feasibility Study for New Nuclear Power Projects (IAEA NE Series No. NG-T-3.3, 2014)	Preparation of a Feasibility Study for New Nuclear Power Projects (IAEA NE Series No. NG-T-3.3, 2014)	Yes	Yes	No	No	No	No
90	IAEA	Preparedness and Response for a Nuclear or Radiological Emergency (IAEA Safety Standards Series No. GSR Part 7, 2015)	Preparedness and Response for a Nuclear or Radiological Emergency (IAEA Safety Standards Series No. GSR Part 7, 2015)	Yes	No	Yes	Yes	Yes	Yes

91	IAEA	Preparedness and Response for a Nuclear or Radiological Emergency General Safety Requirements, No. GSR Part 7	https://www.iaea.org/publications/10905/preparedness-and-response-for-a-nuclear-or-radiological-emergency	Yes	Yes	Yes	Yes	Yes	Yes
92	IAEA	Procurement Engineering and Supply Chain Guidelines in Support of Operation and Maintenance of Nuclear Facilities (IAEA Nuclear Energy Series No. NP-T-3.21, 2016)	Procurement Engineering and Supply Chain Guidelines in Support of Operation and Maintenance of Nuclear Facilities (IAEA Nuclear Energy Series No. NP-T-3.21, 2016)	Yes	No	Yes	Yes	Yes	Yes
93	IAEA	Procurement (IAEA E-learning Module)	Procurement (IAEA E-learning Module)	Yes	No	Yes	Yes	Yes	Yes
94	IAEA	Project Management in Nuclear Power Plant Construction: Guidelines and Experience (IAEA NE Series No. NP-T-2.7, 2012)	Project Management in Nuclear Power Plant Construction: Guidelines and Experience (IAEA NE Series No. NP-T-2.7, 2012)	Yes	No	Yes	Yes	Yes	Yes
95	IAEA	Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage (INFCIRC/566, 1998)	Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage (INFCIRC/566, 1998)	Yes					
96	IAEA	Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (IAEA Safety	Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (IAEA Safety Standards Series No. GSR Part 3, 2014)	Yes	No	Yes	Yes	Yes	Yes

		Standards Series No. GSR Part 3, 2014)							
97	IAEA	Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards General Safety Requirements, No. GSR Part 3	https://www.iaea.org/publications/8930/radiation-protection-and-safety-of-radiation-sources-international-basic-safety-standards	Yes	Yes	Yes	Yes	Yes	Yes
98	IAEA	Radiation Protection Aspects of Design for Nuclear Power Plants (IAEA Safety Standards Series No. NS-G-1.13, 2005)	Radiation Protection Aspects of Design for Nuclear Power Plants (IAEA Safety Standards Series No. NS-G-1.13, 2005)	Yes	Yes	Yes	Yes	Yes	Yes
99	IAEA	Recruitment, Qualification and Training of Personnel for Nuclear Power Plants (IAEA Safety Standards Series No. NS-G-2.8, 2002)	Recruitment, Qualification and Training of Personnel for Nuclear Power Plants (IAEA Safety Standards Series No. NS-G-2.8, 2002)	Yes	No	Yes	Yes	Yes	Yes
100	IAEA	Regulations for the Safe Transport of Radioactive Material Specific Safety Requirements, No. SSR-6	https://www.iaea.org/publications/12288/regulations-for-the-safe-transport-of-radioactive-material	Yes	Yes	Yes	Yes	Yes	Yes
101	IAEA	Regulatory Control of Radioactive Discharges to the Environment (IAEA	Regulatory Control of Radioactive Discharges to the Environment (IAEA Safety Standards Series No. GSG-9, 2018)	Yes	Yes	Yes	Yes	Yes	Yes

		Safety Standards Series No. GSG-9, 2018)							
102	IAEA	Responsibilities and Capabilities of Owner/Operators in the Development of a National Infrastructure for Nuclear Power (IAEA NE Series No. NG-T-3.1, Rev.1 2020)	Responsibilities and Capabilities of Owner/Operators in the Development of a National Infrastructure for Nuclear Power (IAEA NE Series No. NG-T-3.1, Rev.1 2020)	Yes	Yes	No	No	No	No
103	IAEA	Safety Assessment for Facilities and Activities General Safety Requirements, No. GSR Part 4	https://www.iaea.org/publications/10884/safety-assessment-for-facilities-and-activities	Yes	Yes	Yes	Yes	Yes	Yes
104	IAEA	Safety Infrastructure (IAEA E-learning Module)	Safety Infrastructure (IAEA E-learning Module)	Yes	Yes	Yes	Yes	Yes	Yes
105	IAEA	Safety of Nuclear Power Plants: Commissioning and Operation Specific Safety Requirements, No. SSR-2/2	https://www.iaea.org/publications/10886/safety-of-nuclear-power-plants-commissioning-and-operation	Yes	Yes	Yes	Yes	Yes	Yes
106	IAEA	Safety of Nuclear Power Plants: Design Specific Safety Requirements, No. SSR-2/1	https://www.iaea.org/publications/10885/safety-of-nuclear-power-plants-design	Yes	Yes	Yes	Yes	Yes	Yes
107	IAEA	Site Evaluation for Nuclear Installations (IAEA Safety	Site Evaluation for Nuclear Installations (IAEA Safety Standards Series No. SSR-1, 2019)	Yes	Yes	Yes	No	No	No

		Standards Series No. SSR-1, 2019)							
108	IAEA	Site Evaluation for Nuclear Installations Specific Safety Requirements, No. NS-R-3	https://www.iaea.org/publications/10882/site-evaluation-for-nuclear-installations	Yes	Yes	Yes	Yes	Yes	Yes
109	IAEA	Site Survey and Site Selection for Nuclear Installations (IAEA Safety Standards Series No. SSG-35, 2015)	Site Survey and Site Selection for Nuclear Installations (IAEA Safety Standards Series No. SSG-35, 2015)	Yes	Yes	Yes	No	No	No
110	IAEA	Siting (IAEA E-learning Module)	Siting (IAEA E-learning Module)	Yes	Yes	Yes	No	No	No
111	IAEA	Spent Fuel and Radioactive Waste Management (IAEA E-learning Module)	Spent Fuel and Radioactive Waste Management (IAEA E-learning Module)	Yes	Yes	Yes	No	Yes	Yes
112	IAEA	Stakeholder Involvement Throughout the Life Cycle of Nuclear Facilities (IAEA NE Series No. NG-T-1.4, 2011)	Stakeholder Involvement Throughout the Life Cycle of Nuclear Facilities (IAEA NE Series No. NG-T-1.4, 2011)	Yes	Yes	Yes	Yes	Yes	Yes
113	IAEA	Stakeholder Involvement (IAEA E-learning Module)	Stakeholder Involvement (IAEA E-learning Module)	Yes	Yes	Yes	Yes	Yes	Yes
114	IAEA	Strategic Environmental Assessment for Nuclear Power Programmes: Guidelines (IAEA Nuclear	Strategic Environmental Assessment for Nuclear Power Programmes: Guidelines (IAEA Nuclear Energy Series No. NG-T-3.17, 2018)	Yes	Yes	Yes	No	No	No

		Energy Series No. NG-T-3.17, 2018)							
115	IAEA	Strengthening the Global Nuclear Safety Regime (INSAG Series No. 21, 2006)	Strengthening the Global Nuclear Safety Regime (INSAG Series No. 21, 2006)	Yes	Yes	Yes	Yes	Yes	Yes
116	IAEA	Systematic Approach to Training (IAEA E-learning Module)	Systematic Approach to Training (IAEA E-learning Module)	Yes	No	Yes	Yes	Yes	Yes
117	IAEA	Technical and Scientific Support Organisations Providing Support to Regulatory Functions (IAEA TECDOC 1835, 2018)	Technical and Scientific Support Organisations Providing Support to Regulatory Functions (IAEA TECDOC 1835, 2018)	Yes	No	Yes	Yes	Yes	Yes
118	IAEA	The 1988 Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention — Explanatory Text (IAEA International Law Series No 5, 2013)	The 1988 Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention — Explanatory Text (IAEA International Law Series No 5, 2013)	Yes					
119	IAEA	The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage — Explanatory	The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage — Explanatory Texts (IAEA International Law Series No 3 (Revised), 2017)	Yes					

		Texts (IAEA International Law Series No 3 (Revised), 2017)							
120	IAEA	The International Legal Framework for Nuclear Security IAEA International Law Series No 4, 2011)	The International Legal Framework for Nuclear Security IAEA International Law Series No 4, 2011)	Yes	Yes	Yes	Yes	Yes	Yes
121	IAEA	The Management System for Nuclear Installations (IAEA Safety Standards Series No. GS-G-3.5, 2009)	The Management System for Nuclear Installations (IAEA Safety Standards Series No. GS-G-3.5, 2009)	Yes	No	Yes	Yes	Yes	Yes
122	IAEA	Use of a Graded Approach in the Application of the Management System Requirements for Facilities and Activities (IAEA TECDOC No. 1740, 2014)	Use of a Graded Approach in the Application of the Management System Requirements for Facilities and Activities (IAEA TECDOC No. 1740, 2014)	Yes	No	Yes	Yes	Yes	Yes
123	IAEA	Workforce Planning for New Nuclear Power Programmes (IAEA NE Series No. NG-T-3.10, 2011)	Workforce Planning for New Nuclear Power Programmes (IAEA NE Series No. NG-T-3.10, 2011)	Yes	Yes	Yes	Yes	Yes	Yes
124	INPO	INPO Evaluation Manual Supplement - WANO-AC PSUR Process	https://login.inpo.org	No	Yes	Yes	Yes	Yes	Yes
125	INPO	INPO PSUR How to Guides	https://login.inpo.org	No	Yes	Yes	Yes	Yes	Yes

126	NI	0004 - A Guide to Good Practice A4 Booklet	0004 - A Guide to Good Practice A4 Booklet	Yes	Yes	Yes	Yes	Yes	Yes
127	NI	Appropriate Conservatism in Safety Cases	Appropriate Conservatism in Safety Cases	Yes	Yes	Yes	Yes	Yes	Yes
128	NI	Best Available Techniques for the Management of the Generation and Disposal of Radioactive Wastes	Best Available Techniques for the Management of the Generation and Disposal of Radioactive Wastes	Yes	Yes	Yes	Yes	Yes	Yes
129	NI	Clearance and Radiological Sentencing: Principles, Process and Practices	Clearance and Radiological Sentencing: Principles, Process and Practices	Yes	Yes	Yes	Yes	Yes	Yes
130	NI	Generational Analysis for the Recruitment and Retention of Talent within the Nuclear Industry	Generational Analysis for the Recruitment and Retention of Talent within the Nuclear Industry	Yes	Yes	Yes	Yes	Yes	Yes
131	NI	Good Practice Guide - Worker exposure durations for Design Base Analysis	Good Practice Guide - Worker exposure durations for Design Base Analysis	Yes	Yes	Yes	Yes	Yes	Yes
132	NI	Good Practice Guide to Criticality Detection	Good Practice Guide to Criticality Detection	Yes	Yes	Yes	Yes	Yes	Yes
133	NI	Good Practice Guide to Supply Chain Mapping	Good Practice Guide to Supply Chain Mapping	Yes	Yes	Yes	Yes	Yes	Yes
134	NI	Good Practice Guide to Supply Chain Quality	Good Practice Guide to Supply Chain Quality	Yes	Yes	Yes	Yes	Yes	Yes

135	NI	Human Performance Blueprint	Human Performance Blueprint	Yes	Yes	Yes	Yes	Yes	Yes
136	NI	Human Performance for Nuclear Leaders Training Standard	Human Performance for Nuclear Leaders Training Standard	Yes	Yes	Yes	Yes	Yes	Yes
137	NI	Independent Oversight - Good Practice Guide	Independent Oversight - Good Practice Guide	Yes	Yes	Yes	Yes	Yes	Yes
138	NI	Industry Guide to Organisational Capability and Resilience	Industry Guide to Organisational Capability and Resilience	Yes	Yes	Yes	Yes	Yes	Yes
139	NI	Key attributes of an excellent Nuclear Security Culture	Key attributes of an excellent Nuclear Security Culture	Yes	Yes	Yes	Yes	Yes	Yes
140	NI	Nuclear Baseline and the Management of Organisational Change Good Practice Guide	Nuclear Baseline and the Management of Organisational Change Good Practice Guide	Yes	Yes	Yes	Yes	Yes	Yes
141	NI	OELG Event Categories	OELG Event Categories	Yes	Yes	Yes	Yes	Yes	Yes
142	NI	Peer Review of Safety Cases	Peer Review of Safety Cases	Yes	Yes	Yes	Yes	Yes	Yes
143	NI	Personal Dosimetry Management - Good Practice Guide	Personal Dosimetry Management - Good Practice Guide	Yes	Yes	Yes	Yes	Yes	Yes
144	NI	Personal Dosimetry Management - Good Practice	Personal Dosimetry Management - Good Practice Guide: Example International Radiation Passbooks	Yes	Yes	Yes	Yes	Yes	Yes

		Guide: Example International Radiation Passbooks							
145	NI	Right First Time Safety Cases: How to write a usable safety case	Right First Time Safety Cases: How to write a usable safety case	Yes	Yes	Yes	Yes	Yes	Yes
146	NI	SPI Good Practice Guide	SPI Good Practice Guide	Yes	Yes	Yes	Yes	Yes	Yes
147	NI	The Application of ALARP to Radiological Risk - A Nuclear Industry Good Practice Guide	The Application of ALARP to Radiological Risk - A Nuclear Industry Good Practice Guide	Yes	Yes	Yes	Yes	Yes	Yes
148	NI	The Periodic Review of Leadership & Management for Safety	The Periodic Review of Leadership & Management for Safety	Yes	Yes	Yes	Yes	Yes	Yes
149	NI	The Selection of Alarm Levels for Personnel Exit Monitors - Operational Monitoring Good Practice Guide	The Selection of Alarm Levels for Personnel Exit Monitors - Operational Monitoring Good Practice Guide	Yes	Yes	Yes	Yes	Yes	Yes
150	NI	UK Nuclear Industry Good Practice Guide to Respiratory Protective Equipment (RPE)	UK Nuclear Industry Good Practice Guide to Respiratory Protective Equipment (RPE)	Yes	Yes	Yes	Yes	Yes	Yes
151	OECD/NEA	Nuclear New Build: Insights into Financing and Project Management(OECD/NEA, No. 7195, 2015)	Nuclear New Build: Insights into Financing and Project Management(OECD/NEA, No. 7195, 2015)	Yes	Yes	Yes	Yes	Yes	No

152	WANO	MN | 2016-1 Conduct of Operational Readiness Assistance (ORA) Missions	https://members.wano.org	No	Yes	Yes	Yes	Yes	Yes
153	WANO	PCD 2013-3 Startup-related Areas for Improvement	https://members.wano.org	No	Yes	Yes	Yes	Yes	Yes
154	WANO	PCD 2013-4 Pre-Startup Reviews Schedules	https://members.wano.org	No	Yes	Yes	Yes	Yes	Yes
155	WANO	PCD 2013-5 Rev3 Scope of SOER Reviews in Pre-Startup Peer Reviews	https://members.wano.org	No	Yes	Yes	Yes	Yes	Yes
156	WANO	PCD 2013-6 Conduct of Pre-Startup Peer Review (PSUR) Crew Performance Observations (CPOs)	https://members.wano.org	No	Yes	Yes	Yes	Yes	Yes
157	WANO	PO&C 2013-2 WANO Pre-Startup Performance Objectives and Criteria,	https://members.wano.org	No	Yes	Yes	Yes	Yes	Yes
158	WANO	WANO Program Guideline WPG 06 Pre Startup Review	https://members.wano.org	No	Yes	Yes	Yes	Yes	Yes
159	WANO	WANO PSUR How to Guides	https://members.wano.org	No	Yes	Yes	Yes	Yes	Yes
160	WANO	WPG 01-PR WANO Peer Reviews	https://members.wano.org	No	Yes	Yes	Yes	Yes	Yes
161	WNA	Nuclear Power Economics and Project	Nuclear Power Economics and Project Structuring (WNA, 2017 Edition)	Yes	Yes	Yes	No	No	No

		Structuring (WNA, 2017 Edition)							
162	WNA	Talking Points	http://members.world-nuclear.org/imis20/CMDownload.aspx?ContentKey=4aca26a2-ed07-4cab-a83e-e1fc4120bf3d&ContentItemKey=17aedc16-63ad-4cd2-9c75-22501269775d	No	Yes	Yes	Yes	Yes	Yes
163	WANO	PL 2013-1 - Traits of a Healthy Nuclear Safety Culture	https://members.wano.org/library/member-support/wano-principles/pl-2013-01-traits-of-a-healthy-nuclear-safety-(1)	No	Yes	Yes	Yes	Yes	Yes
164	WANO	GL 2013-1 - Traits of a Healthy Nuclear Safety Culture	https://members.wano.org/library/member-support/wano-guidelines/gl-2013-1-traits-of-a-healthy-nuclear-safety-cul	No	Yes	Yes	Yes	Yes	Yes
165	WANO	PO&C 2019-1 - WANO Performance Objectives and Criteria	https://members.wano.org/library/po-c-and-manuals/po-cs/po-c-2019-1	No	Yes	Yes	Yes	Yes	Yes
166	IAEA	Safety Reports Series No. 74 - Safety Culture In Pre-Operational Phases Of Nuclear Power Plant Projects	https://www.iaea.org/publications/8792/safety-culture-in-pre-operational-phases-of-nuclear-power-plant-projects	Yes	Yes	Yes	Yes	Yes	Yes
167	IAEA	NP-T-1.4 Implementing Digital Instrumentation and Control Systems in the Modernization of Nuclear Power Plants	https://www.iaea.org/publications/8057/implementing-digital-instrumentation-and-control-systems-in-the-modernization-of-nuclear-power-plants	Yes					

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Robert Fisher

Industry CNO, NUAWG Executive Sponsor

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