White Paper

Nuclear Plants with an Owner's Manual

A quest to improve next generation nuclear plant operation, maintenance and safety

Summary: *New nuclear construction is closer than ever after thirty years. Nuclear generation meets national security objectives, reduces carbon footprint, while improving quality of life. Before pouring new concrete, three decades of commercial nuclear operations need review for improvements. These should include ways to improve safety, simplify operations and reduce costs. What lessons do thirty years of nuclear operations hold for next generation commercial nuclear plants? Integrating design basis methods to carry operations forward not only improves safety, but offers better performance and lowers costs. This paper discusses early lessons learned for new plant construction, operations and technical maintenance support.* [1]

Introduction

Nuclear plants were under construction in 1979 when Three Mile Island (TMI) occurred. Last generation plants used the best technology available then, but lack of North American nuclear construction has reduced technology awareness thirty years later. When the last nuclear plants were built, mainframe computers powered networks, personal computers and distributed controls remained to develop, and relational databases didn't exist. Technology has fundamentally changed how other industries manage information. New technologies will change nuclear plant construction, operations and maintenance methods.

Every plant design generation has technical challenges; each new generation provides a new opportunity to surmount known problems. TMI issues still concern the nuclear industry today. Unavailable equipment, operations, equipment control, and design basis continuity are just a few. Plant's design basis, Probabilistic Risk Assessment (PRA), and other design/operations incongruence obscure operating risks. NUREG 0737, *Clarification of TMI Action Plan Requirements* listed concerns. Though resolved for existing plants, post-TMI lessons warrant review before building the next nuclear plant generation.

10CFR50 governed the last nuclear plant generation's licensing. Nuclear plant designers hypothetically determined worst case accident sequences deterministically. Limiting "design basis" events could identify, in principle, the ultimate set of plant design requirements. These established foundations around which plant equipment to mitigate those accidents was designed. Design Basis Accident (DBA) mitigation defined a special set of "safety related" equipment. Safety-related equipment fundamentally protects the public heath and safety by preventing or mitigating nuclear accidents. Safety-related and nonsafety-related establish two fundamental nuclear classes. The public depends on one of two broad equipment classes which cover all plant equipment. Though supporting generation, nonsafety-related equipment (in principle) does not affect public health and safety. Safety-related equipment protects the public from nuclear accidents. Two rules, 10CFR50 Appendices A & B specify how safety-related equipment must be better, through design (Appendix A) and quality assurance (Appendix B).

Plant design bases identify equipment's end purpose. Safety-related design basis equipment receives special treatment to assure its performance protects the public health and safety. "Special treatments" give critical attention beyond ordinary engineering due diligence to assure nuclear safety SSC function under the worst possible conditions. Appendices (10CFR50) A & B rules specify safety-related equipment design basis requirements.

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[1] *In this paper, "treatment" identifies structures, systems and components (SSC) requirements that assure SSC can perform its safety related design functions. Most treatments are specified in 10CFR50 Appendices A & B. (Here, Preventive Maintenance 'PM' is used synonymously with 'scheduled maintenance,' as one form of special treatment that manages equipment failures to assure reliability. 'Operations' broadly includes all practices needed to operate plants, including design basis development controls.)*

Practical Safety-related Equipment Work Problems

Pre-nuclear power technology developed skills of many craftsmen, technicians and engineers. Fossil generation was different, so those installing or maintaining nuclear equipment faced a new challenge – learning nuclear processes. March 28, 1979 was the wake-up call starting up General Public Utilities Unit 2 – Three Mile Island (TMI). TMI revealed a gulf between idealized and implemented nuclear plant operations. Contributors included maintenance practices. Large amounts of equipment were out of service. Tagged equipment out-of-service contributed to loss of control events. Some tags physically blocked operators' views. Operators charged to maintain public health and safety were ineffective, and that had to change.

Following TMI, Appendix B Quality Programs acquired new meaning. Appendix B maintenance programs needed QC inspectors, but few were skilled craftsmen. Most had been apprentice electricians, mechanics and technicians attracted by higher pay. Younger QC charged with enforcing rules had to convey technical requirements they didn't understand. Formally trained professional engineers and managers weren't qualified much better. Rarely had even the best little more than cursory knowledge of 10CFR50 program requirements. Older, experienced nuclear engineers knew rules from experience. Human factors presented problems developing and controlling quality technical work.

Early plant designs were first of a kind. TMI "lessons-learned" changed designs, and that required revised Final Safety Analysis Reports (FSARs). Events modified original plant design bases, though updated FSARs lagged. New post-TMI safety-related equipment had never been maintained before. P&IDs, master equipment lists (MELs), vender manuals and systems descriptions supported performing work. Key work order system fields of manual plant trouble reports captured some history details. With service experience, newly degreed, many early engineers developed equipment reliability programs. Looking at another plant's experience from that era, I can recall some early work challenges. Operating at low availability, some plants saw sporadic operations, regular work operations crises, and intimidating equipment work backlogs. Equipment failures captured imaginations. Every critical equipment failure had moments of fleeting interest, fading away as it was replaced with the next failure.

Maintaining equipment takes spare parts. Many plants lacked consumables or replacement parts needed at startup. Few safety-related spare parts were available. Safety-related systems or components, like control rod drive assemblies, also had many nonsafety-related parts. The component's primary function – controlling reactivity – was safety related. No one had ever analyzed most equipment below the assembly level for noncritical functions, and in those early days organizations lacked sophistication.

By happenstance, our plant engaged several A/E engineers to help us with technical modifications on nuclear fuel handling equipment. The seniors ("greybeards") demonstrated most nuclear fuel handling machine (FHM) components, except the pressure shell boundary, were not safety-related from FSAR accident analysis. Failures within the FHM machine proper – cables, limit switches and contacts had been analyzed and found unable to cause public health and safety consequences by failing. FSAR accident analysis excluded FHM internal parts failures causing accidents affecting offsite doses while moving fuel. Thus most of the parts and equipment we had assumed were safety-related (as subcomponents) were – in fact – not. Now, this was an eye-opener. Suddenly we could procure safety-related equipment subcomponents with commercial grade certifications and no other encumbrances! Paper intimidation barrier gone, we could now undertake deferred work.

Our Engineering Department had developed a 10CFR50 dedication process, which provided another tool. Nuclear process awareness continued growing with our understanding of the plant design basis. FSAR component accident safety analyses supported dedication. Having a complete design basis makes dedication processes easier, for qualified, trained engineers. Dedication for procurement requires familiarity with not only the plant design, but underlying nuclear design quality control processes. Using dedication, engineers can technically assure that specified equipment design basis safety function requirements are met with procurement. (Nonsafety-related equipment has no nuclear safety functions – in principle.)

Realization that some safety systems' subtier equipment and parts had no safety functions first struck us dumb. We began solving part procurement delays with improved, faster procurements. Rules required evaluating safety-related equipment parts for analyzed accidents risk contribution. Where evaluation showed no affected safety functions, we could procure to commercial grade standards. Even where safety functions existed, identifying those functions for standard application treatments based upon similar applications sped our safety-related equipment analysis. We extended procurement capabilities to commercial dedication, which develops the paper trails needed to procure safety-related equipment.

Separating safety-related and nonsafety-related categories assures that nuclear safety-related equipment receives specified treatments. These include traceability, inspections and tests, post maintenance test, hold or witness points, written procedures. Treatments assure design equipment performs its safety functions – even during abnormal events. With Regulatory Guides, NUREGs and other guidance, 10CFR50 identifies approximately fifteen fundamental special treatments. Most reflect tasks a competent engineer would otherwise specify, exercising due diligence to procure parts that meet industry codes and standards.

Regulation, politics, and control issues delayed post-TMI work. Eager inspectors tagged work nonconforming for many reasons, some valid, others not. Nonconforming parts were scrapped, with many green engineers unfamiliar with nuclear program requirements unable to disposition tags for any further use. One inspector tagged crane-suspended control rod assemblies, stopping work. Crews set down loads – a 6000 pound control rod drive and orificing assembly – under legal action threat. Of course, safe work practices precluded leaving a suspended load on an overhead crane not in use. To resolve paperwork minimally took hours, often much longer. Tagging everything nonconforming "scrap" for was easy. Supervisors refereed workers, inspectors, or engineers facing work shutdowns. No one sought to violate confusing rules, but resolving legal technicalities on the work floor was hard. Hourly workers didn't concern themselves with work progression; completing work just wasn't in their contract. Most workers, even hourly, worked professionally as quickly as possible. Interpreting legal fine points became the professional engineer's primary responsibility. However, though capable people, some lost nuclear work ardor. Fighting city hall to perform routine maintenance wasn't very satisfying to hands-on craft workers. Crafts people relinquished technical difficulties and work shutdowns for engineers and managers to resolve.

As interpreted in the 1980's, unintended work consequences resulted from Appendix B "Q" Quality. Conscientious workers and supervisors lost work completion accountability. Timely, predictable work processes emerged too late for useful effect for our plant's operations. Workers were not at fault. Our resident inspector said our procedures were inadequate. Our schedules showed lack of work control, and workers often said parts were unavailable. Dispositioning nonconformances, QA controlled work completion progress. Schedules were beyond plant control. Short outages became shutdowns, longer shutdowns and then protracted outages. Plant reliability and availability plummeted. Low production, expensive maintenance, high costs, and growing local anti-plant sentiment culminated in pulling the financial plug. The Public Utility Commission (PUC) saw no alternative but to take the plant out of the rate base. Forced from the rate base, the company (in crisis) finally sought improving organizational work processes. However, timing was late. Continued income losses forced shutdown.

Activities besides procurements lacked conformance; process methods were also tagged nonconforming. Difficult detection inspections required disassembling prestressing tendon looking for failed button heads. Inspectors found predictive techniques to identify prestressing tendons bearing plate wire corrosion inadequate. Since predictive detection was imperfect – accurate only 83% of the time finding bundle wires corrosion[2], they reasoned it was nonconforming. Imperfect diagnostic techniques were nonconforming! Performing lengthy, expensive tendon wires detensioning visual inspections continued undeterred by promising in-place testing examination. Early nuclear maintenance expectations occurred deterministically. Today, even ASME ISI code cases don't expect diagnostic perfection – not even for pressure piping crack diagnosis. Ordinarily, statistical confidence tests would apply. But early rules, qualified workers, calibrations, and quality processes had to be applied with perfection in those early days.

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[2] based on subsequent visual exam

Use of design margin by codes and standards was unclear. Diagnostic approvals resided in engineering, outside maintenance, the responsible department. Disqualifying diagnostic PM – or other proactive work was easy – and less risky than developing qualification tests!

Our plant had substantial overlapping responsibilities. After several weeks of job analysis for worker qualification requirements, one exasperated examiner exclaimed, "How many of you are responsible for maintenance?!" Well, one way or (small m) maintenance was done by

- ❖ Maintenance
- ❖ Scheduling and Planning
- ❖ Engineering (Maintenance Support)
- ❖ Results (I& C)
- ❖ Site Engineering
- ❖ Fuel handling
- ❖ Operations
- ❖ Quality Control
- ❖ Chemistry

Completed plants that are abandoned benefit few. Failure to maintain the design basis, tolerating excessive procedure errors, allowing high costs or all combined together caused loss of confidence. While efficient, effective operations benefit many, plant shutdowns benefit fewer. Abandoned projects like Fort St. Vrain, Zimmer, Rancho Seco, Trojan, Shoreham, Washington Power 1& 3, Marble Hill, Millstone 3 constitute a lengthy honor role. New technology caused some shutdowns. Post-TMI redesign delays raised construction costs playing a role in others. Plant closures hurt the nuclear industry, souring investors. On-schedule projects serve the public interest well. New plant construction provides new opportunities to do nuclear work right. New plant buyers should expect more from next generation's plant designers. They need

- Confidence in the plant's design basis
- Clear understanding of technology risks
- Due diligence:
    - ❖ Purchasing a finished plant design
    - ❖ Translation of the finished design into useable Appendix B & other component classifications for
        - ▪ plant part lists
        - ▪ failure analysis
        - ▪ work planning
    - ❖ Simple, responsible organizational structures
    - ❖ Integrated organizational accountability for operations
- Clearly defined processes like construction or maintenance
- Known maintenance plans, processes & costs (for post construction operations)
- Predictable schedules and cost
- Reliable power generation

In playing card terms, plant operators need a full deck. Early nuclear stories cite ambiguous rules and developmental environments that nurtured confusion, creating conflict in high-stakes nuclear operations. Comparably good money, job prestige, and community respect didn't control high turnover. Workers never sought anything short of doing the best possible job. Yet as one inspector's trademark phrase put it, "Finding quality here is like finding chastity in a brothel." His targets weren't workers, engineers or managers, but the designed, as-built plant and its nuclear processes. Quality absence root causes weren't inadequately trained staff, non-licensed engineers, technicians or mechanics performing substandard work. It wasn't purchasers, mechanics and inspectors buying, installing and performing substandard work with poor quality parts. Nor was startup design documentation the problem. Industrial nuclear supplier support wasn't missing, either (though some went bankrupt servicing the industry). Trained workers, adequate budgets, and strong cultural support processes create strong nuclear operations. Buying-into nuclear cheaply, fixing problems reactively later on-the-fly contributed to TMI, and hurt the industry in general.

Many problem origins traced back to design bases, and adequately transferring their requirements to the plant workers as procedures, specifications, operations, maintenance staffing, and other needs that critically depend on quality information. Maintaining original design ties through adequate design basis relationships allows the plant to be a good as its design itself. Generation IV designs have come a long way, baby!

What do Generation IV New Plants Need?

Plants need complete design basis information. Source documents should be easily retrievable, supporting fast, accurate routine decisions for processes like purchasing. New plant owners should not need to redevelop or recreate their design basis for routine parts orders, or other work. First generation plant owners couldn't foresee nuclear plant documentation needs, nor will they ever be perfect, but routine information uses should be integral with data sources. Transcription reentry should be minimal. Constructing a plant, an Architect Engineer (A/E) develops a design basis. Why recreate their design basis over and over, especially considering new standard designs? Why not archive the original plant design's construction details for the future operators for continuing use over the operating plant lifetime? The complete design basis development opportunity occurs once in plant's life – designing and constructing the original plant. Why redevelop basic source information, given the alternative? Information management tools available today offer this option.

Comprehensive plant operations project outage needs and maintenance costs. The Maintenance Rule requires that operators consider maintenance impact on standby equipment availability. Doing maintenance in outages that could be done online adds to cost. Experience establishes cost history, in the absence of exact cost estimating. Designers should identify plant licensed operations modes to project comprehensive scheduled maintenance plans and estimate costs. Owners should receive standard plant designs documented to provide comprehensive new plant operating and maintenance plans, as if they were new car buyers. The complete *user's manual* should help owner's anticipate all plant operating requirements. The approved, licensed maintenance plan should be accessible to workers by local area network. More complete designs supporting competitive plant purchase decisions would better fulfill NRC policy goals to advance new innovative, safer plant designs.

Standardization philosophy extends downstream. Standard plant designs support standard work processes, equipment treatment, procurement requisitions, corrective maintenance, tests, inspections, certification and other operations requirements. Standardization starts at the design-level. Standardized risk classifications, scheduled maintenance, spare parts, failure reporting and functional requirements potentially simplify many aspects of nuclear plant work. Work planning, scheduling, reporting and even HP reviews could streamline work identification, estimation and planning. Commercial aviation standards simplified air transport regulatory work, reducing costs over the past half century. Completed, preapproved nuclear maintenance plans would eliminate maintenance overlaps, inconsistencies, redundancies and rework-caused equipment failure contributors.

Classification's Objective: Specify Special Treatments

Plant master equipment lists (MEL) identify safety-related (SR), Maintenance Rule risk significant (RS) and Quality "Q" special treatment classification. Plants classify other requirements, such as INPO AP-913 Critical classification, or 10CFR20 Health Physics Requirements. Risk classifications help specify equipment treatments. Developed clearly, classifications guide treatment selection to simplify and streamline work. "Q-coded procurements get receipt inspection," "Safety-related equipment failures get Part 72 report reviews," "Irradiated or contaminated plant system work orders get radiation work permit (RWP) reviews," and so forth. Incomplete or improper specification increases risks of error. For example, a health physics classification code incorrectly identifying normally contaminated plant areas as "clean" would create a hazard. Streamlined methods of any kind require process controls, due diligence and defense in depth.

Incomplete equipment subtier quality codes over-classify risk. Some schemes end risk classification at the system level. System level classification never examines subsystems and part system functional contributions. Where safety-related system embedded equipment and parts lack safety functions, evaluation could re-classify those equipment's parts nonsafety related. Safety classification requires relating equipment failures with system functions, in cascading detail. Incompletely specified function roles require equipment parts to meet unnecessarily high SR procurement standards. Unnecessarily high standards slow procurement raising costs. Further, classification depends on specific failure (mode) effects on functions. Databases classify equipment and required treatments effectively. Equipment classification supports work – consistently classifying equipment safety risk to apply special treatments, and perform appropriate work. Together, they assure design basis safety-related performance.

Site specific PRAs establish risk significance and special treatments. Based on probabilistic risk principles, PRA classifies end use risk significance like deterministic classification at completion. ASME Section III and Section XI[3] Nuclear Pressure Vessel/In Service Inspection (ISI) & In-service Test (IST) requirements provide additional pressure vessel and inservice test treatment requirements. Special treatments include maintenance effectiveness reporting (see 10CFR50.65, the Maintenance Rule). However, looking back 50.65 measures only suggest future performance. Directly, rules require few maintenance treatments. Venders may prescribe mandatory safety-related equipment maintenance, explicitly. However, few vender maintenance requirements are mandatory. Some non-NSSS venders specify EQ maintenance (ASCo solenoid valves and Agastat time delay relays) per 10CFR50.49, but even these cases are rare.

Programs should specify part-level scheduled maintenance treatments. Knowing a pump "fails to pump" is intrinsically interesting, but the maintainer must answer, 'why won't it pump?' Without that insight the maintainer has little recourse available to "maintain the pump" except replace it. For many failures this is not only unnecessary, but uneconomic if cause can be determined. Classification without cause-effect relationship diminishes its value. Uniformly applied ER classifications develop all PM treatments the same. Treatment selected depends on classification. Classifying risk for information purposes provides no benefits. Environmental Qualification (EQ) 50.49 requires replacement of electrical safety-related equipment based on thermal-aging life. EQ 50.49 materials and equipment consequences require specific vender guidance. Before 50.49, only nuclear reactor NSSS components had well-defined lifetimes specified by original equipment manufacturers (OEM). Replacing B4C absorber assured depleted control materials replenishment for reactor control. (This should be obvious.) Part aging function requirements can be quite complex. With tens of thousands of component material that age, tracing nuclear plant part replacements was (is) a complex administrative chore. Documents have limited part-level utility at the plant level assuring maintenance performance. Scheduled maintenance CMMS/EAMS programs offered more assurance.[4]

AP-913, *Equipment Reliability Process*, specifies nuclear critical equipment PM maintenance. Critical equipment requires scheduled maintenance, planning, monitoring parameter limits, trending performance and failure trending. Critical equipment owners expect equipment cross-system component failure trending (along with EPIX failure trending) evaluation. Failing, critical equipment requires corrective action. The Maintenance Rule requires trending availability, reporting functional failures. Repetitive critical equipment failure corrective actions should use root cause analysis. Programs must evaluate repetitive failing equipment for long-term replacement.

Administrative FSAR sections provide general requirements including work control. ANSI N18.7, "Maintenance and Modifications," addresses maintenance. NRC rules may endorse consensus standards that delineate formal requirements. Administrative procedures address plant maintenance. However, like common law, many maintenance practices are still known primarily by performance. Consider, for example, methods that apply PM treatments to SR system components. How are failure threats identified for treatments? How are treatments selected? How are their performance intervals applied? Even today

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[3] Boiler and Pressure Vessel Code

[4] One reason 50.49 Environmental Qualification was difficult for plants was their lack of methods to assure aging expired equipment would be replaced upon end-of-life. Alone, this created powerful CMMS/EAMS system needs.

due diligence and experience are the failure engineer's primary guides. In part, this explains variations in treatments, intervals and methods – and their outcomes – service life, seen across the nuclear industry today.

Safety-related equipment requires *as found* failure cause evaluation. Safety-related equipment failure review for Equipment Performance and Information Exchange (EPIX) reportability, as well as failure trending, creates an industry failure database to investigate for corrective action. Some plants trend all equipment trouble reports for component level failures, others just safety related. The maintenance rule requires system level failure system availability (by train) and maintenance preventable function failures (MPFF) evaluation. Performance-based measures identify system health by component and train. Statistically, analyzing more failures improve results – understanding of failure processes. Failure statistical review will always be a difficult chore, however.

Design determines operation modes maintenance tag-outs. Maintenance tag-outs must be ready at the time (and point) of emerging work – before work starts. Scheduled maintenance needs preplanned tag-outs. Developing pre-operational tag-out reduces operations support pressure. Known tag-outs shouldn't need to be created during an outage. Tag-outs depend on plant layout, process flow and designs specified in P&ID plant design documents. Design basis improves tag-outs. Developing and maintaining advanced plans (before work) enhances safety. Complex, expensive maintenance plans, like replacing control rod drive absorbers, should be available prior to startup. Routine maintenance procedures should be developed at design approval – before startup. Providing procedures before new plant construction turnover greatly reduces risk of not having them developed, available when needed. Planning also reduces exposures. While fast-track Engineer-Procure-Construct (EPC) methods improve construction schedules, they also detract from the quality of the final delivered design. Design-dependent tools the design basis can generate in advance of construction should be verified adequate to meet current industry standard operations, maintenance and engineering practices. Doing so practices "due diligence," reducing later work-arounds and costs.

New plants should avoid scheduled maintenance experimentation. The plant's surveillance test (ST) program provides the failure-finding test framework upon which to build PM. Ignoring risk significance presents a one-size-fits-all equipment PM approach. Applying common component templates uniformly to same-type equipment ignoring context creates large, difficult to maintain programs. For the last plants, users prescribed manufacturers' recommended task intervals without regard to service or risk. Large programs over-prescribed PM. Standby equipment continuous duty treatments didn't factor service into selected intervals. Without application context adjustments, tasks are ineffective, and may even be destructive (over-lubricating motors, for example).

Classifying equipment should base selected PM tasks on risk. Today, few plant PM programs formally apply PM treatments based upon risk. To do so requires effectively identifying not only component, but component subtier part failure risks, relating PM treatment basis to equipment tags. Traditional legacy maintenance database hierarchies simply don't have that capability. Without relational databases, the task is impossible. The average nuclear plant MEL has well-over 40,000 critical components per unit. These average several failure modes per component, and support around 50 systems with >5 safety significant functions each. Without resorting to computational permutations, exact task development would be practically impossible to specify without systematic, consistent simplification tools. Fortunately, those tools are available today. We can design and build plans for the next plant generation with unprecedented exactness only dreamed about forty years ago!

Systematic Approach

Developing systematic PM tasks requires relational data to account for plant system risks, design symmetries, and complexity while tracking functional requirements. Standardization demands similar component template resources. Relationships must be repeatable, consistent, measurable and updateable. Legacy programs, built with text documents or even spreadsheets, aren't readily traceable, maintainable nor able to perform cross-cutting failure trending or other objective requirements called for by AP-913 standards, much less manage parts time or cost accounting. Practically, databases make design traceability possible. Spreadsheets (at best) manage flat, two-dimensional relationship structures – and that only with difficulty. Documents are entirely non-relational.

Function classification relates equipment hardware failures with systems' functionality. Techniques can add new equipment update, install replacements, or change system functionality. Systems-level functions capture detailed subsystem requirements. Integrated leak rate checks exemplify the ideal system-equipment relationship: measuring a single system characteristic (leakage) that identifies multiple subcomponent failures.

Effective treatments address failure. Failure prevention starts at the part failure level. Many plants classify equipment criticality or risk, yet never specify related PM treatments. Others use classification for informal guidance. If classification never specifies PM end use treatments, it has no purpose. Classification helps users manage risks. Risk should determine PM treatments (even multiple PM treatments), treatment intervals (safe life limits and more stringent intervals for higher-risk non direct failure levels), and quality of treatment (more effective, expensive PM treatment for higher-risk failures). Formally selecting and applying treatments commensurate with risk incorporates safety-risk philosophy. The greater system-controlled safety function risk, the greater the corresponding loss consequences, in safety terms. More risk justifies applying more expensive, conservative or even multiple treatments.

Applying risk-based treatments requires managing large data systems. Consider NEI 00-04, *10 CFR 50.69 SSC Categorization Guideline*, "Risk Assessment Worksheets" (page 51). For a typical nuclear unit with 100,000 tagged components, SSC failure risks classification requires hundreds of thousands of worksheet analyses summaries alone. PM treatment selection hasn't even started! PDF file retrieval systems can numerically catalog many tag worksheets PDF documents. Value comes from integrating the data relationally, however. NASA Space Shuttle PDF design documents number well over 300,000 documents; their commercial venders proudly market their systems can manage that application as part files. Permutations and combinations grow even more quickly, and the real work hasn't begun. Relational databases provide the most effective, consistent way to organize and retrieve quality information from analysis for end use – fast.

Few rules directly guide nuclear plant maintenance. Performance-based 50.65 reports indirectly predict maintenance program effectiveness. Based on industry literature, INPO primarily fosters maintenance excellence practices like six-sigma or total quality maintenance. Unlike nuclear plant operators (or air commercial air transport counterparts' requirements), nuclear plant maintenance specialists like machinists or mechanics, though very skilled and often apprenticed into craftsmen, aren't licensed. Clarification of TMI Action Plan Requirements (NUREG-0737)[5] in 1982 raised maintenance flags. Post-TMI lesson recovery plans suggested improvement. CFR50.65, the Maintenance Rule, ultimately introduced risk-informed, performance-based nuclear maintenance regulation. Other industries regulate maintenance risk differently. FAA civil aircraft maintenance certifies mechanics. Airworthiness aircraft certifications require a certified maintenance program. All airframes – commercial airliners or otherwise – trace airworthiness to a certified design. Traceable, quality documents completed by certified professionals identify and track part-level failures for analysis. Though highly skilled and qualified, nuclear maintenance staffing programs don't have equivalent certification standards today.

Design is the best time to establish the plant design basis. Designers know why they specify equipment layouts, redundancies and configurations to provide functions with hardware they select and install in systems. Why cripple operations later to regenerate information known once by designers? In principle, the design basis must be available for design approval. That information should remain available integrally for the life of the plant. New licensees should be provided comprehensive documentation at the time of design. New standard plant designs reuse over and over particularly justifies this effort. Standardization justifies complete plans with complete justifying design basis. Providing complete plans demonstrates due diligence. While impossible thirty years ago, relational data structures available today develop design basis materials from original designs. Standard designs, fully-implemented as consensus maintenance plans

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[5] Action Plan, NUREG-0660, provides a comprehensive and integrated plan to improve safety at power reactors

would simplify maintenance requirements, while assuring operations as they have in the commercial airline industry. Public health and safety warrants an integrated, standardized approach for Generation IV nuclear plants.

Conclusion

New designs should provide better, safer more reliable nuclear units. The next nuclear plant generation must operate with the complete set of operating tools, including complete design basis information effectively providing a real-time owner's manual. Standardizing new plant designs should carry downstream into operations, including maintenance. Designs should provide standard design basis SSC classifications, dominant failures and failure-dependent treatments to simplify end use requirements. Standard plant designs systems, functions, master equipment lists, supplied equipment, equipment templates, failure modes, related management strategies, tasks and works orders as integrated design implementation would easily follow. The design basis should provide useful user tools. The next nuclear plant generation's operators should get the owner's manual – complete, presented as modern relational database technology information.

Licensed nuclear plant designs should include standard design-dependent end use special treatments relationally. Developer tools accessible from GUI Windows-based interfaces should allow users to develop, plan, initiate, assess and update analyzed design risks, performing routine tasks like procedure development, procurement, parts refurbishments, overhauls, and scheduled maintenance. Starting new Generation IV nuclear plants like Generation I & II units forty years ago would not be in the public interest. Standardization should integrally extend designs downstream into operating materials. Thirty years ago, we primarily provided owners their FSAR, Systems Descriptions, P&ID drawings and MEL. There should be more today. Staffs use design basis information daily to operate. Materials need standardization. Delivered plants should not redevelop complex design materials only designers – as source contributors, would ever know.