Brains vs Brawn: Towards a Comprehensive Asset Management Strategy for Nuclear Power Plants

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ABSTRACT

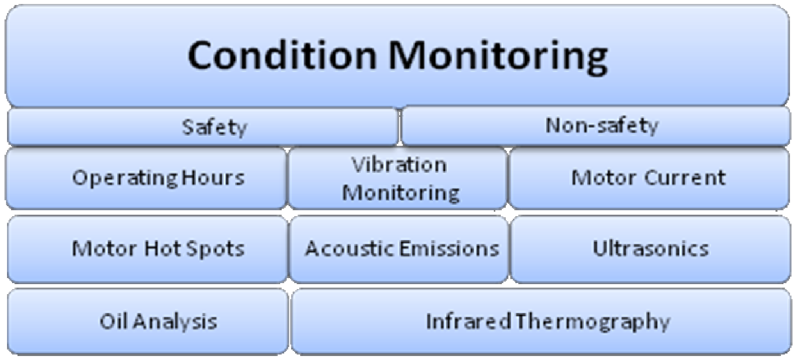
From the boots on the ground at the plant to the executive suite, asset management means different things to different people. All definitions of asset management, however, boil down to this core function: Converting raw data and observations (sensors, operator rounds, etc) about equipment and components into information and knowledge that is then used, propagated, shared, and deployed by the human resources and digital components to manage the asset. Asset management, which also can be thought of as knowledge management, involves I&C, automation, condition monitoring, reliability centered maintenance, inventory and stock, training, and myriad plant monitoring, diagnostic, and performance software functions.

Nuclear plants, of course, have special needs, given the level of safety and reliability necessary and relentless regulatory requirements. In this paper, the authors articulate an asset management strategy for new nuclear plants that seeks to integrate, at least conceptually, the knowledge needs of all the stakeholders for a nuclear plant - plant operations and maintenance staff, centralized fleet management, corporate engineering, owner/operator executives, regulators, and applicable industry asset management standards.

INTRODUCTION

Asset management has many definitions, depending on the perspective and context of the people involved.

A person at the plant responsible for the performance of a pump, for example, might refer to the on-line condition monitors or monitoring system, together with the operator rounds of data collected regularly, periodically, or intermittently, as asset management. Condition monitoring, as shown below, is part of asset management, but not all of it.



At the owner/operator executive level, the asset management system is probably thought of more in terms of the business management systems (e.g., SAP, IBM, Oracle, etc) which specifically link to the power plant data and digital systems.

In between the boots-on-the-ground plant level asset management and the system at the corporate/enterprise level are several other critical elements of "asset management." For example, the on-line condition monitoring system data, the off-line or periodic condition testing data, other monitored process and supervisory variables, and predictive analytics software can all be combined with work processes and procedures to form the "reliability centered maintenance" system. Any or all of the elements just described in turn have logical interfaces with the computerized maintenance management system, stores and inventory management systems, central or corporate engineering department, the centralized or multi-asset portfolio performance monitoring facility, the outage planning and scheduling processes, and so on.

While there are many ways to view asset management, the essence of all of them boils down to this: Converting raw data and observations (sensors, operator rounds, etc) about equipment and components into information and knowledge that is then used, propagated, shared, and deployed by the human resources and digital and automation components to monitor, assess, control, and *manage* the asset.

Part of the design of a power plant today has to include the design and engineering of a system that will create and disseminate the data and knowledge about all of the components of the asset, especially the critical ones upon which the financial performance of that asset depends, throughout the owner/operator organization. This is especially critical for an asset as complex as a nuclear power plant. The "asset management" system needs to incorporate all of the items listed above, as well as support the regulatory requirements surrounding each component, each procedure, and each action or decision.

One of the greatest challenges today in new plant design, engineering, and construction is to ensure that the asset management "system" is compatible with the existing business and plant level systems the owner/operator currently uses. It's a great challenge because for the most part, the asset management system is in fact fragmented among different pieces of software, often found in various functional "silos" (e.g., operations, maintenance, environmental, health, and safety, I&C, regulatory, etc) throughout the organization at operating plants and associated staff. For new plants, a variety of programs (which include the software platform and the man-hour services that go with it) are available for reliability-centered maintenance (RCM), asset management (AM), and enterprise management systems that include asset management components. The "Asset Management Systems," of basic Engineering Technical Specification for a new nuclear plant, may only cover the plant-level definition of asset management and *component condition monitoring systems*. This document is to help all those associated with new and existing nuclear units think more broadly about the problem. *At a minimum, the design team needs to be in constant interface with the owner/operator's IT, Operations (at existing plants), and Asset Management divisions, as well as the I&C/automation system supplier, to ensure that a holistic perspective is being taken on plant-level "systems."*

REGULATORY REQUIREMENTS

The motivation for developing a more comprehensive asset management program should come from the need for comprehensive knowledge management for the owner/operator over the asset life cycle. It also comes from the regulatory side. Title 10 CFR Part 52 requires "reliability assurance programs" (RAP) for nuclear safety-related equipment.

Additionally, NRC distinguishes between design basis RAP (D-RAP) and operations basis (O-RAP). The reliability so achieved must also support the probabilistic risk assessment (PRA) of specific components. In other words, specific safety-related equipment must achieve a reliability factor sufficient to support the PRA which is part and parcel of the certified reactor designs. However, no consensus exists regarding what, exactly, is required to directly fulfill the RAP intent.

The RAP is, in effect, a scheduled maintenance plan. Scheduled maintenance has to be integrated into the reliability centered maintenance program, to maximize safety and minimize cost. Licensing new designs includes certifying a complete reliability assurance program (RAP). A prospective licensee's ITAACs (Inspections, Tests, and Analyses Acceptance Criteria) verify final conformance to specifications that assure safe operations. Completing the ITAACs allows the finished certified licensed plant to operate. One ITAAC addresses a key part of design, RAP. Although various NRC requirements and industry practices address specific reliability of specific parts of the plant piecemeal, there is not an integrated program that addresses plant reliability holistically and comprehensively.

Today, the nuclear plant vendor provides the master equipment list (MEL) to meet combined operating license (COL) requirements for RAP. However, this should only be considered the bare minimum, something like minimum daily requirements of vitamins and nutrients – enough to keep you alive but not near enough to thrive. Even something like the maintenance rule 10CFR50.65, that is triggered when the D-RAP transitions into O-RAP, should not be considered an adequate RAP.

The RAP should answer the question, "what activities make this piece of equipment reliable?" We could extend this by saying the RAP should include everything working together and integrated that makes a piece of equipment reliable, including:

- On-line sensors and monitoring devices with which the component is equipped
- Periodic and regular condition-based data taken on that equipment (e.g., operator rounds and hand-held instrument data)
- Predictive analytics and monitoring methods and software governing the equipment

- Availability of spares and consumables required by that equipment
- Visibility of the data and information about that equipment to decision-makers through the maintenance management software
- Automation of work orders and tasks required by the equipment
- Ease with which data and information about the equipment is accessed by the appropriate people and organized and presented to make it most useful
- Criticality of that equipment with respect the availability and safety of the plant
- Similarity, familiarity, and uniformity of the processes and procedures with other nuclear plant assets under the responsibility of the owner/operator.

Therefore, even if a comprehensive system governing the knowledge around the asset isn't a practical goal during the design phase, then a comprehensive RAP should be. In both cases, the system, comprising the human, digital, and hardware elements, has to be conceptualized, designed, and engineered holistically, accounting for how data and information will flow among the various human and digital elements of the system – from component to executive suite.

BACKGROUND

The physical design of a new power station or unit follows an established process, which includes the instrumentation and control (I&C) and automation systems, often called the distributed control system (DCS). There is also emerging for the latest nuclear plant designs a process for designing an enterprise-wide data management platform or infrastructure. Physical plant design involves the architect engineering firm, the reactor and sub-system vendors, the automation system supplier, project managers, construction managers, etc. Enterprise software suppliers work with the owner/operator to design and build out the "digital data platform."

Typically, though, there is not an established and accepted process for the design of the plant's *asset management system*, which can be thought of as the link (or several links) between the physical iron and steel in the ground, or *brawn*, and the enterprise data and information management infrastructure, or *brain*. The term "asset management" has become a buzz phrase and therefore its definition amorphous and vague. However, for our purposes, asset management refers to the various software and digital elements that take data inputs from the plant, convert that data into pieces of information or knowledge, and then disseminate that knowledge to those who need to access it. It will, for example, include various equipment condition monitoring systems, an equipment reliability program or standard, and/or reliability-centered maintenance (RCM) program, a comprehensive asset management system is much more.

The asset management "system" integrates the data and information from the physical assets with the virtual or digital elements and the human processes. The asset management "system" also may need to comply with, or at least consider, various existing or pending industry standards, including INPO AP913, NEI's Standard Nuclear Performance Model, PAS 55, probabilistic Safety Assessment (PSA) Models, EPRI Planned Maintenance (PM) Templates, Communities of Practice (COP) guidelines, DOE/EPRI Aging Management Programs, and/or IAEA TECDOC 1305 (discussed in later sections of this report), or some version of a Reliability Assurance Program (RAP) as described previously.

Finally, and perhaps most importantly, the asset management system must be compatible with the plant and business process systems employed by the owner/operator and the various processes and procedures uniformly applied across the owner/operators fleet of nuclear assets.

An intelligently designed asset management system must integrate many or all of the following sub-systems and software and work processes:

- Appropriate on-line monitoring and sensing devices on the physical components
  - Vibration monitoring
  - Corrosion and/or wear monitoring
  - Motor current
  - Acoustic emissions
  - Temperature
  - Wear (erosion, corrosion, and aging)
  - Many others depending on the component
- Remote performance monitoring (such as by centralized engineering and operations)
- The plant data historian
- Computerized maintenance management or work management software
- Reliability (RCM) and predictive, preventive, and proactive maintenance programs
- Thermal performance monitoring software
- Alarm management software
- Visualization and performance dashboard platforms
- Radiation monitoring and exposure
- Security, movement, and access
- Configuration management
- Change management
- Human factors engineering
- Equipment Condition monitoring (e.g., vibration, temperature, etc)
- Operator rounds and data from hand-held devices
  - Motor hot spots, Infrared thermography
  - Ultrasonic measurement
  - Oil analysis and tribology
- Predictive analytics software
- Process optimization software
- 2-D or 3-D visualization software
- Inventory, supply chain, and outage management software
- Project management and scheduling software

Drawing on experience from fossil plants, staff engineers often receive performance and O&M related data and information on their cell phones or PDAs. One power plant today may have several thousand process and sensor points. Correspondingly a fleet of large coal-fired supercritical units may have as part of its asset management system over 300,000 "tags," process data points that represent monitored data points, calculations, or information points. These process sensors and data points become the raw material of the owner/operators asset management program. Oil and gas facilities are beginning to deploy *3-D visualization technology such that all the asset management data and information is* *organized around actual 3-D representations (developed by laser scanning the actual plant) of the as-built (and ever-changing) plant.*

CRITICAL EQUIPMENT AND SYSTEMS

An early step in all asset management programs is to identify and classify all plant equipment based on how critical it is to the continued and/or safe operation of the plant. This exercise is similar to determining the level of monitoring and protection given to any particular component (such as in PIP PCERE001, Rotating Equipment Monitoring Guidelines), and is based on such factors as effect on production, expense and complexity of repairs, environmental health and safety risk, operator presence, and location. *For nuclear plants, the critical vs non-critical determination is complicated by the safety vs non-safety system designation that affects everything nuclear, with respect to regulatory compliance*.

Some of the criteria that will determine the importance of individual equipment in a nuclear plant include:

- Safe shutdown
- Safety related equipment
- Equipment essential to power operation
- Triggers maintenance rule functional failure
- Environmental qualification
- Station blackout
- Fire protection
- Anticipated transient without SCRAM
- Pressurized thermal shock

There are dozens of excellent reasons why an asset management strategy needs to be developed so that the *design of the asset management system can take place distinct from, but concurrent with, and informed by, the design and engineering of the physical plant and the data management infrastructure and architecture*:

1. The software and hardware components listed earlier are at the bleeding edge of technology, and therefore are constantly being updated and improved. The design of the asset management system must evolve with the evolving digital technology that will support it.
2. Each owner-operators culture and ways of doing things are different. The asset management strategy must be designed to reflect these differences. Rather than simply buying software loaded onto the computers and servers that will come with the plant from the automation supplier, there should be an intelligent design and rationalization of all the software and digital elements.
3. Because vendors who supply asset management software components overlap to a great extent, there's money to be saved by developing a strategy and determining who supplies what. It should be the responsibility of the owner-operator to rationalize supply so that you don't buy

what you don't need or won't use. In addition, there are potentially millions that could be saved in software licensing fees by consolidating and integrating software.

4. A well thought out asset management strategy could save significant funds in the physical plant if redundancy, spares, and excess capacity are rationalized against the most advanced means of monitoring and managing operational risks. For example, a variety of "soft sensor" technologies could replace hard-wired sensing used traditionally.
5. Nuclear owner/operators in the U.S. have been glacially slow in adopting digital technology for the obvious reasons of regulatory acceptance. Nevertheless, the next units built will have no choice but to adopt digital technology because the old technology is obsolete and isn't offered any longer.
6. One monitored data point from a plant component will de distributed, propagated, and used by multiple human experts as well as by these various software systems. Some monitored points may be critical from the standpoint of asset management and therefore the quality of the sensor purchased, the redundancy, etc, may need to be re-assessed. It is important to remember that *the automation system vendor is specifying and purchasing sensors and control elements to meet the control strategy, not the asset management strategy*.
7. The actions which will need to be taken by operators, maintenance crews, technicians, engineers, managers, outsourced services suppliers, traders, regulators, etc, as a result of this data and information will vary in time scales. For example, electricity output is traded through ISOs and RTOs in real-time, day-ahead markets, or under long-term bilateral contracts. Some maintenance and inspections are done routinely daily or hourly; large maintenance projects are done during outages.
8. Some of these software systems, especially in the thermal performance and predictive analytics and condition monitoring areas, will have their performance and usefulness optimized only if the data input requirements to the software is properly thought through. *In other words, there are key measurements in the plant that can optimize the asset management suite and some of these measurements/monitored points may not be the same as the ones for the automation system*. Powerful predictive analytics programs can often avoid the need for certain sensors and monitored points.
9. The plant's asset management system will then have to be integrated into the business and corporate processes, or the enterprise management software..
10. Cyber-security standards and processes will govern all digital elements of asset management.

Obviously, an asset management program can't anticipate all the requirements before plant operation begins, nor would it be prudent from a cost standpoint to make it all encompassing. However, the critical exercise is to make sure that the critical pieces of equipment are adequately addressed, risk factors are included to make judgments, etc.

DIGITAL ASSET INTELLIGENCE

Pearl Street Inc and others have gone as far as to suggest the power industry needs to think in terms of a *digital asset intelligence* (DAI) system that would be the responsibility of the Chief Asset Intelligence Officer (CAIO), or Chief Asset Intelligence Owners-Engineer, for the project or the company. In the case of a new project, the CAIO, who should be separate and distinct from the architect-engineer (AE), the engineer-procure-construct (EPC) contractor, automation system supplier, etc, should have his/her own team of asset intelligence specialists. Others have advocated the "development of a hybrid digital expert who is trained in software and communications as well as mechanical and electrical theory" and the creation of "digital groups and work practice areas, not just for software portions of projects but for maintenance, design, and operations as well."

Several of the objectives of the asset management system design and specification should be: (1) failure analysis of critical components shall be integrated electronically/digitally into computerized maintenance system; (2) asset performance data for critical equipment shall be collected automatically in real time; (3) the system shall support continuous improvement teams for condition based and reliability-centered maintenance activities; (4) monitored data from the actual equipment – as opposed to generic equipment models – shall be used to build models that automate workflows, parts ordering and inventory, etc. Of course, in a real-world setting, the critical equipment has to be identified, the costs for such objectives evaluated, etc. *The point is that these questions will only be adequately addressed through distinct asset management design effort by digital asset intelligence specialists*.

RELEVANT INDUSTRY WORK

Since the next generation of U.S. nuclear unit projects are only now moving forward into the design and project management stage (from generic design and NRC approval stages), the concept of designing a suitable asset management system is only now being considered. There are some important industry activities that staff should factor into the asset management strategy.

INPO AP 913, Equipment Reliability Standard. This standard [Ref 8] is undoubtedly familiar to U.S. nuclear owner/operators. While it certainly could be considered the foundation for a nuclear asset management program, today it is likely only a piece of a more sophisticated approach. Of critical note, though, is AP913, Appendix G, "Considerations for Building Equipment Reliability. At a minimum, the design of the asset management system, the hardware, software, and digital elements, should be shaped to meet these requirements, to automate those aspects that are repetitive (such as acceptance checks), include new technologies for condition monitoring, etc.

Standard Nuclear Performance Model [Ref 7]. The Standard Nuclear Performance Model (SNPM), rev 5 (2007), developed by INPO, NEI, and the Electric Utility Cost Group (EUCG), identifies core processes, such as plant operation, work management, supply chain, equipment reliability and configuration management, and then enabling processes, information technology, information management, human resources, business services/asset management, training, loss prevention, and support services.

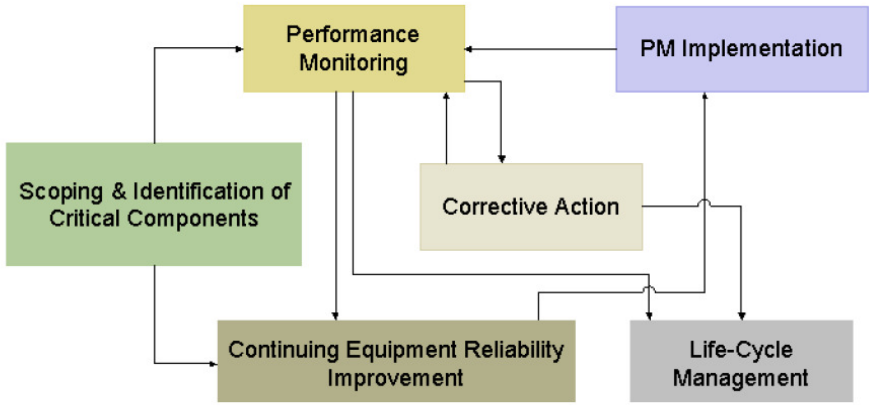
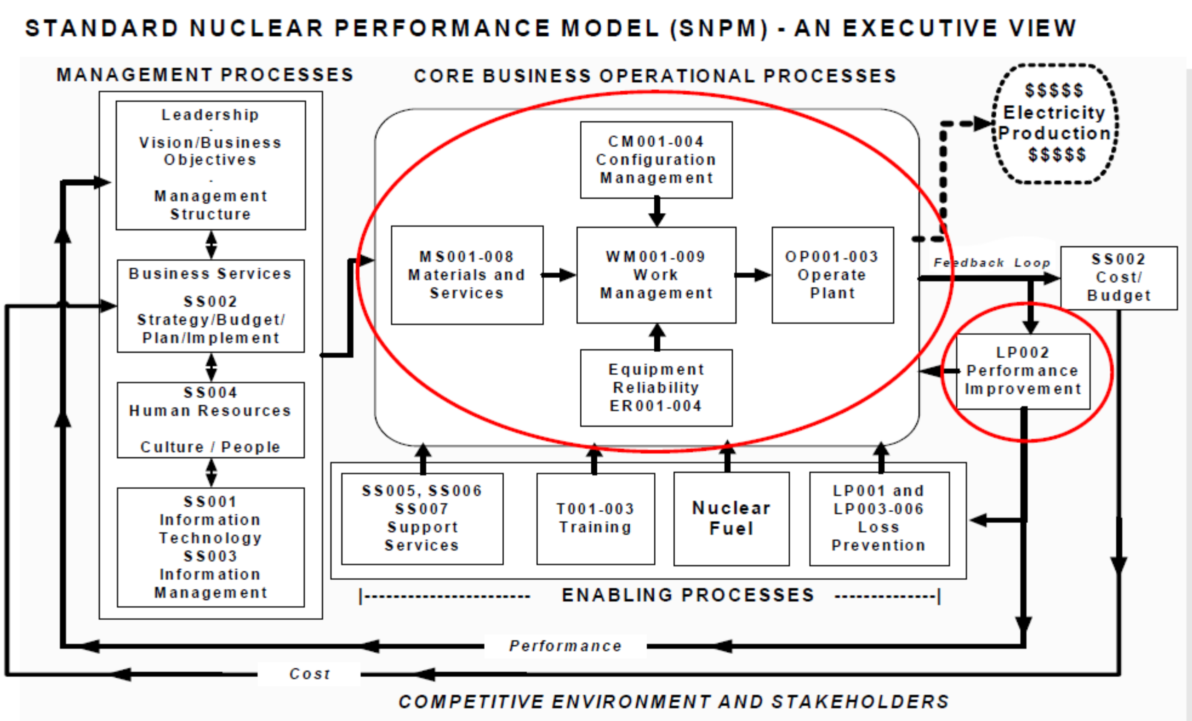


Figure 1- INPO AP-913 Equipment Reliability Process

To illustrate how the DAI design team would think through the application of the SNPM, consider the following example in which a component requires a repetitive maintenance task because of a failure in a part. The failures are documented in a corrective action system. The equipment reliability process is then applied to analyze the failure and determine if a modification is required and, if so, alternatives are recommended. When an alternative is selected and a design is approved, plant budgets are altered accordingly. Configuration management process creates a design change. The execution of the modification is done through the work management process. New parts are added, old parts are deleted, supported by the materials services and supply chain process. The training process could also be pressed into service.



PAS 55 Asset Management Standard. This is a relatively recent standard that has been developed and promoted by UK companies (with mandatory compliance by utility companies), and appears to be gaining some traction in Europe, but there's little awareness in the U.S. at this time. Asset management is defined in this standard as "systematic and coordinated activities and practices through which an organization optimally manages its assets and its asset systems, their associated performance, risks and expenditures over their life cycles, for the purposes of achieving its organizational strategic plan." For our purposes, the emphasis should be on the "asset system." Interestingly, this standard recommends creating a chief asset officer in the company executive suite. PAS 55 has sections that deal with asset configuration, calibration, and maintenance; planning, development, schedules and resource allocation; spare parts management; maintenance, inspection, and testing of systems; management of change and risk mitigation; performance and condition monitoring; and investigation of asset related failures, incidents, and non-conformities. A traditional RCM program, familiar to nuclear plant owner/operators, might be adapted for compliance with certain sections of PAS 55.

IAEA-TECDOC-1305, Life Cycle Management. While this document [Ref 13] addresses many of the issues embodied by asset management systems, it appears to be too general and too old (issued in 2002 although there may be revisions) to be of use for today's nuclear plants.

PUTTING IT ALL TOGETHER

Although at the plant level, a condition monitoring system, shown in light blue in the graphic below, might be considered "asset management," a comprehensive strategy has to go farther and deeper.

Other key parts would include the digital elements of: the reliability-centered maintenance (RCM) program; outage and maintenance management, especially as anchored by the computerized maintenance management system (CMMS); and operations and performance monitoring. Equipment condition monitoring is really just one element of an advanced maintenance strategy.

Asset management strategy should also go beyond the plant boundaries. Owner/operators with large fleets of power plant assets have moved to a centralized fleet monitoring facility, where engineering and technical expertise is shared among many assets. The asset management strategy needs to consider which functions will be distributed at the plants and which will be handled centrally. Regulatory requirements, along with the burdens of documentation and reporting, should also be included. For nuclear units, regulatory requirements are embodied by the combined operating license (COL), D-RAP, O-RAP, ITAACS, Quality Assurance Program, and the Maintenance Rule 10CFR50.65. Finally, the requirements of industry standards such as INPO AP-913, SNPM, NERC Reliability Standards, and PAS 55 should be factored in.

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