Reducing Risk for the Next Generation Nuclear Plant

John M. Beck II,
208-526-4248
john.beck@inl.gov

Harold J. Heydt,
208-526-7802
harold.heydt@inl.gov

Emmanuel O. Opare,
208-526-0189
emmanuel.opare@inl.gov

Kyle B. Oswald
208-526-4863
kyle.oswald@inl.gov

Idaho National Laboratory
2525 N. Fremont Ave.
P.O. Box 1625
Idaho Falls, ID 83415-3780

Abstract. The Next Generation Nuclear Plant (NGNP) Project, managed by the Idaho National Laboratory (INL), is directed by the *Energy Policy Act of 2005*, to research, develop, design, construct, and operate a prototype forth generation nuclear reactor to meet the needs of the 21st Century. As with all large projects developing and deploying new technologies, the NGNP has numerous risks that need to be identified, tracked, mitigated, and reduced in order for successful project completion.

A Risk Management Plan (RMP) was created to outline the process the INL is using to manage the risks and reduction strategies for the NGNP Project. Integral to the RMP is the development and use of a Risk Management System (RMS). The RMS is a tool that supports management and monitoring of the project risks. The RMS does not only contain a risk register, but other functionality that allows decision makers, engineering staff, and technology researchers to review and monitor the risks as the project matures.

Introduction

Risks are present in all projects, regardless of scope, cost, and schedule. Managing those risks is often an overwhelming task if not carefully planned for and orchestrated. A comprehensive Risk Management Plan (RMP) and associated tools are being used for the NGNP Project.

This paper highlights some of the approaches the Next Generation Nuclear Plant (NGNP) Project uses in developing its RMP and defines the scope and methodology for identifying, analyzing, responding, determining impact, reporting, tracking, and closing risks that could prevent the NGNP project from achieving its objectives. The objective of risk management is to identify above normal risks for the selective application of appropriate response actions to reduce or mitigate such risks to acceptable levels. This paper also introduces the audience with the NGNP Risk Management System (RMS). The RMS is a relational database developed which provides conventional database utility as well as a number of unique capabilities specifically designed to facilitate the development and execution of activities outlined in the RMP. These include the capability to establish the risk baseline; document and analyze the risk reduction plan; track the

current risk reduction status; and organize risks by reference configuration area, system, subsystem, and component.

Risk management is a key discipline for making effective decisions and communicating the results within and across organizations. It is used to determine the feasibility of project plans, identify potential problems that may affect life-cycle activities and the quality and performance of products, and improve the active management of projects. The purpose of risk management is to identify potential programmatic and technical problems before they occur so that actions can be taken to reduce or eliminate the probability of occurrence and/or impact of these problems should they occur.

Background

The Next Generation Nuclear Plant Project is defined by The Energy Policy Act of 2005 (H.R. 6), which was signed into law by President of the United States in August 2005, requires the Secretary of the U.S. Department of Energy (DOE) to establish the Next Generation Nuclear Plant (NGNP) Project. According to the Energy Policy Act:

> *The NGNP Project shall consist of the research, development, design, construction, and operation of a prototype plant (to be referred to herein as the NGNP) that (1) includes a nuclear reactor based on the research and development activities supported by the Generation IV Nuclear Energy Systems initiative, and (2) shall be used to generate electricity, to produce hydrogen, or to both generate electricity and produce hydrogen.*

The NGNP Project supports both the national need to develop safe, clean, economical nuclear energy and the Nuclear Hydrogen Initiative, which has the goal of establishing greenhouse-gas-free technologies for the production of hydrogen. The DOE has selected the helium-cooled High Temperature Gas-Cooled Reactor (HTGR) as the reactor concept to be used for the NGNP because it is the only near-term Generation IV concept that has the capability to provide process heat at the high temperatures necessary for highly efficient production of hydrogen.

Technology Readiness Assessment for the NGNP

The NGNP project uses a Technology Readiness Assessment (TRA) process to determine the technology maturity of critical PASSCs and then to roadmap the required maturity pathway. As a technology is studied, tested, designed, and matured, its risk is reduced as its technical maturity is increased. This process is depicted in Figure 1. For the NGNP project, establishing and executing Technology Development Roadmaps (TDRMs) as a plan for maturing technologies is the primary method for managing and mitigating risk. These TDRMs chart the path to mature technologies from the current Technology Readiness Level (TRL) to successive readiness levels.
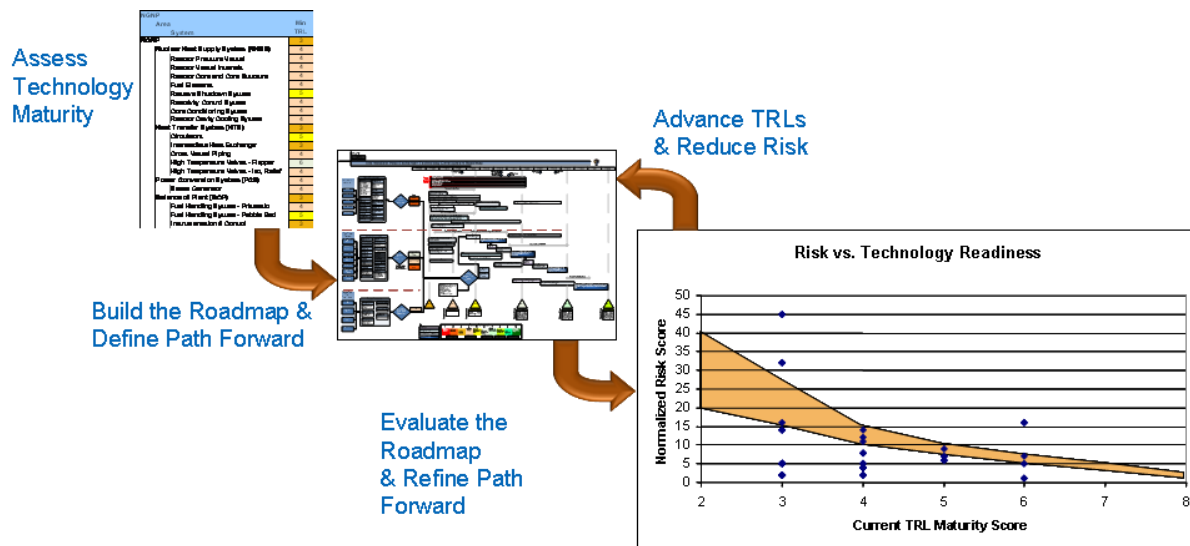
Figure 1. Roadmapping and Risk Reduction - An Iterative Process

Technology Readiness Level

The Technology Readiness Assessment process originates with NASA and the U.S. Department of Defense (DOD) and evaluates the deployment readiness of a technology and its readiness to function in an integrated environment. The NGNP uses TRLs with a tailored scale of 1 to 10 (see Figure 2 below) compared to the standard 1 to 9 scale used by NASA and DOD. The additional rating allows the NGNP to assess readiness for full commercialization following the construction and successful operation of the NGNP.

Technology Readiness Levels are an input to inform NGNP project management of the readiness of a particular technology, component, or system. For TRLs 1-5, assessment typically occurs on an individual technology or component with a calculated roll up TRL for the associated area, systems, and subsystems. As the technology or component progress to further levels of maturity, integrated testing occurs and allows TRL assessments directly against subsystems and systems. The integrated testing or modeling occurs at increasingly larger scales and in increasingly relevant environments, thus achieving higher TRL ratings.

The risk analysis method is a conventional risk management methodology used to assess known risks. However, many of the NGNP technologies are less mature, leading to higher uncertainty in design parameters and risks that may not be known. To estimate the level of unknown risk associated with the performance of these technologies, a measure of technical maturity, called the Technology Readiness Level (TRL), will be used. An assessment of TRLs for the critical NGNP PASSCs complements the conventional risk assessment for technical risks and is an integral part of the risk management strategy.

Definitions for the TRLs were established, as show in Table 1, and initial TRL estimates were made for critical Plant, Area, System, Subsystem, and Components (PASSCs) by the reactor suppliers. Technology development roadmaps were established to define the steps necessary to advance the TRLs in selected areas. Roadmaps outline the Engineering, Licensing, and R&D efforts, the known risks that they address, and the anticipated effect on the TRLs. Each task focuses on reducing known risk, increasing TRLs, or both.

The technology roadmaps, and the associated tasks depicted, have been adopted into the risk-response plans for the risks that they address. As part of a response plan, the extent to which a technology is matured and the risk reduced by each task is quantified. Assuming a task is successful, the expected completion date for the task becomes the date upon which the risk is reduced. This can be displayed in a risk waterfall chart, like the one shown in Figure 3. The Risk Management System is the system used to analyze the risk data and generate the NGNP risk waterfall charts. Figure 3 shows the risk is reduced each time a relevant piece of information is gathered from a task that reduces known uncertainty or increases technology maturity.

Table 1. TRL scale and criteria

| TRL	Criteria
1	Basic principles observed and reported.
2	Technology concept and or application formulated.
3	Analytical and experimental critical function and/or characteristic proof of concept: Lab level for pieces of components.
4	Lab-scale component validation in lab environment: Demonstrate technical feasibility and functionality. Beginning of integration of some interfacing components into sub-assemblies.
5	Lab-scale component or sub-assembly validation in relevant environment. Beginning of integration of sub-assemblies into sub-systems.
6	Subsystem model or prototypical scale demonstration in relevant environment.
7	Subsystem prototype demonstration in an operational environment. Beginning integration of subsystems into complete system.
8	Total system completed, tested and fully demonstrated and validated.
9	Total system used successfully in project operations.
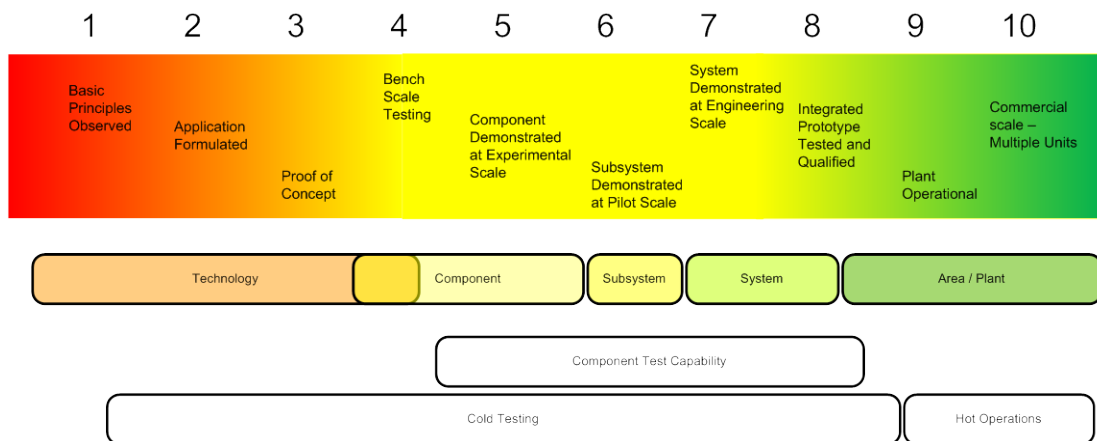
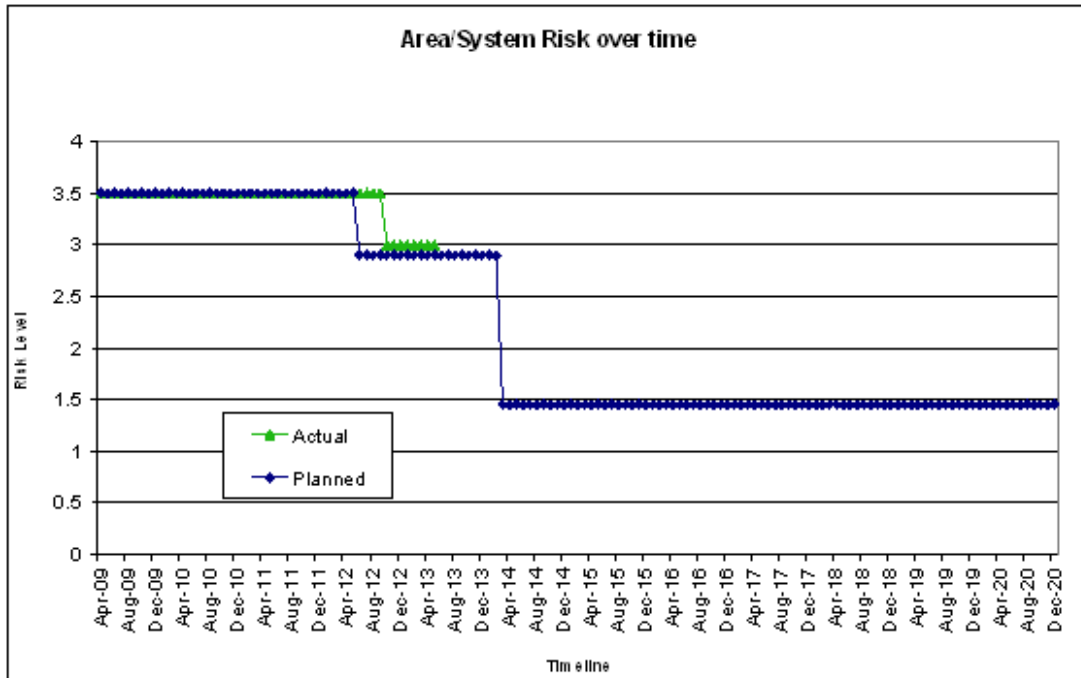Figure 2. Technology Readiness Levels.

Figure 3. Risk Waterfall Chart.

Risk Register

The Risk Register is a standard tool used to collect identified risks from various resources. Risks are managed through the Risk Register and are maintained for the entire length of the project. If many cases, such as Department of Energy projects, the amount of time the risks are stored is a multi-year requirement. The Risk Register has numerous attributes that need to be maintained and are significant during all phases of the project life cycle.

Included in the Risk Register is the assignment of risks to specific type. Risk types include both technical and programmatic risks and are defined in the International Council on Systems Engineering (INCOSE) *Systems Engineering Handbook*, version 3.1, as follows:

Technical risk is the possibility that a technical requirement of the system may not be achieved in the system life cycle. Technical risk exists if the system may fail to achieve performance requirements; to meet operability, producibility, testability, integration requirements; or to meet environmental protection requirements. A potential failure to meet any requirement which can be expressed in technical terms is a source of technical risk.

Programmatic risk is produced by events which are beyond the control of the project manager. These events often are produced by decisions made by personnel at higher levels of authority. Programmatic risks can be produced by reductions in project priority, by delays in receiving authorization to proceed with a project, by reduced or delayed funding or by changes in licensing, enterprise, or national objectives.

The RMP is the primary product of the risk management planning function. Risk management planning includes activities necessary to establish and maintain the project's process for managing risks.

Risk Identification

The purpose of the risk identification function is to identify risk events likely to prevent the project from achieving its objectives and to document specific characteristics with a basis describing why these events are considered a risk. All identified above-normal risks are entered into the project risk management system and tracked through closure. Risks are identified and documented, and tracking is initiated in this phase. Because risks change as the project matures with new risks developing or anticipated risks disappearing, risk identification is a repetitive process.

The steps performed within this function of the project risk management process are (1) identification of preliminary above-normal risks, (2) documentation of risks to provide complete identification, including bases, and (3) initiation of risk tracking.

Risk identification includes three functions, (1) Identify risks, (2) document identified risks, and (3) initiate risk tracking. Each of these three identification function are orientated around specific tasks and activities to obtain a set of risks for the project.

Risk Analysis and Quantification

The method used to analyze, score, and determine the risk level for each risk item is described below. Risk analysis is completed so that risks are prioritized and assigned an appropriate risk-handling strategy. Risks are evaluated for each applicable scenario (e.g., prismatic versus pebble-bed). The steps performed within the function to perform risk analysis and quantification are illustrated in Figure 4. There are four specific steps associated with risk analysis and quantification, they being (1) semi-quantitative analysis, (2) perform risk analysis, (3) assign risk level, and (4) supporting risk analysis methods.
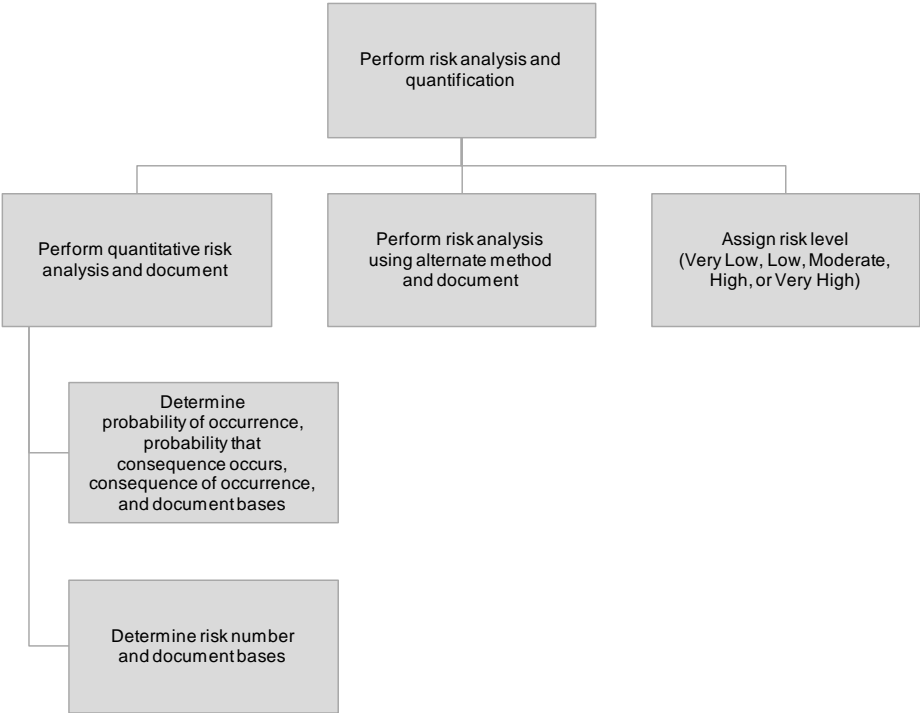

Figure 4. Risk-analysis and quantification.

Semi-Quantitative Analysis

Risks are analyzed using a semi-quantitative method involving calculation of a numerical risk number for each event. This risk number is based on a relative numerical value assigned to the likelihood (event probability or P_E) that a risk event will occur, the associated impacts of the risk (consequences or C), and the likelihood (P_C) that the event will result in the consequence identified. These factors are used to calculate the risk number according to the following equation:

Risk Number = (P_E x P_C) x C x W   EQN (1)

Where:

P_E = Probability of occurrence

P_C = Probability that consequence occurs at level of severity noted

C = Consequence of occurrence (loss if event occurs)

W = Weighting factor (used to emphasize consequence of occurrence)

Values are assigned to all four factors according to the criteria in Table 2 and Table 3. In general, the discrete factor values shown in the tables are used in the calculation; however, exceptions can be made to increase dispersion and discriminate between risks. In this case, an appropriate basis and annotation must be provided. For the factors P_E & C, the value assigned should reflect the risk condition before implementation of the risk-handling strategy. Factor P_C, is set to one (1) and will be modified in the future as designs are changed to reduce consequence and probability of consequence. The weighting factor is applied to the risk calculation to force a higher risk rating for risk of high consequence; the weighting factor also recognizes the lower confidence in the users' ability to predict probability levels.

Table 2. Probability Definition.

Probabilities	Range	Technology Criteria	Scale Criteria	Use for Calculation
Beyond Design Basis	**< 10⁻⁴**		Not evaluated since it is improbable	**N/A**
Very Unlikely	**10^{-4} to <0.1%**	Technology is well understood and is routinely used in similar, integrated applications and conditions	The scale of the system/ component needed is similar to existing successful applications.	**0.1**
Unlikely	**0.1% to <1%**	Technology is understood and has been used in applications and conditions close to, but not identical to, required conditions. A small amount of development is needed before deployment.	Majority of the components are similar in scale to existing applications.	**0.3**
Somewhat Likely	**1% to <10%**	Technology needs a moderate amount of research, development and design before deployment at required operating conditions.	About half of the components are similar in scale to existing applications	**0.5**
Likely	**10% to 50%**	Technology needs a major amount of research, development and design before deployment at required operating conditions.	Some of the components are scaled similar to existing applications, with the remainder needing significant design changes to achieve deployment.	**0.7**
Very Likely	**> 50%**	Low maturity, complex, unclear development path; multiple unproven technology must work together.	All needed components have never been attempted at the necessary scale.	**0.9**

Table 3. Consequence Definition.

Consequence	Technical	Schedule	Use for Calculation (risk units)
Negligible	Minimal or no impact.	Schedule delays that do not affect milestones or the critical path.	1
Marginal	Small change needed to design or path forward. Minor damage to equipment or facilities. Minor, temporary loss of capabilities.	Schedule delays that may affect external milestones or are threatening a slip along the critical path.	3
Significant	Moderate change needed to design or path forward. Moderate, but repairable damage to equipment or facilities. Moderate, temporary loss of capability	Schedule delays that will slip the critical path end date by up to 6 months.	5
Critical	Major change needed to design or path forward, workaround available. Significant, repairable damage to equipment or facilities.	Schedule delays that will slip the critical path end date by more than 6 months but less than 1 year.	7
Crisis	Major change needed to design or path forward, no workaround available now. Loss of equipment or facilities.	Schedule delays that will slip the critical path end date 1 year (schedule slips in excess of 1 year are anticipated to cause a loss of the program).	9

Risk numbers are used to prioritize risks and determine the risk level (i.e., very low, low, moderate, high, or very high) of each event. Risk levels are used to tailor appropriate risk-handling strategies, and also define tracking requirements. Levels can generally be defined by the following criteria:

Very-Low Risk: A risk identified as very low has virtually no potential for impacting the project or the consequences are exceptionally minor. No oversight is necessary.

Low Risk: A risk identified as low has little potential for impacting cost, schedule, or performance requirements, and is probably mitigated with standard cost or schedule contingency. Minimum oversight is needed to ensure the risk remains low.

Moderate Risk: A risk identified as moderate has a reasonable probability of impacting cost, schedule, or performance requirements; and in turn requires additional management actions above the normal contingency and project controls.

High Risk: A risk identified as high has a strong possibility of a major impact to the project and will require additional significant action to control risk (e.g., comprehensive analysis and a formal RMP).

Very-High Risk: A risk identified as very high is almost certain to occur and/or have a major impact on the project. Like a high risk, it will also require considerable action to control the risk (e.g., comprehensive analysis and formal RMP).

Semi-Quantitative Analysis Activities

The semi-quantitative risk analysis involves the following:

1. Determine the probability of occurrence (P_E) for the risk item using criteria in Table 2.

   a. Select the appropriate qualitative descriptor in the risk register, and the associated numerical value is assigned automatically.

b. Document the basis for the probability of occurrence (P_E) in the risk register with documented results from historical occurrence data, research, tests, comparable applications, or other objective, verifiable means.

2. Determine the probability of consequence (P_C) being realized for the risk item.

a. As a default, set the probability of consequence to 1.0. If no information is available to discriminate the value when each risk has been or will be realized, leave probability of consequence set to 1.0.

b. If information is available to discriminate amongst the probabilities of consequence, select the appropriate qualitative descriptor in the risk register, and the numerical value is assigned automatically.

3. Determine the consequence of occurrence (C) for the risk item using the criteria in Table 3.

a. Select the appropriate qualitative descriptor in the risk register, and the associated numerical value is assigned automatically. If a risk has multiple consequences and meets criteria in more than one of the ratings blocks, the "worst" consequence should be selected.

b. Document the basis for the consequence of occurrence (C) rating in the risk register with documented results from historical occurrence data, research, tests, comparable applications, or other objective, verifiable means. At a minimum, this should include a justification or rationale for the rating and whether it applies for the duration of all project phases or for the activity being assessed.

Perform Risk Analysis

Initially, the factors in the risk number calculation (P_E, P_C, and C in Equation 1) will be numerical values based on the ranges identified in Section 0 and the associated tables. The risk number for a particular risk event will only have meaning when compared to risk numbers for other events. Ultimately, the goal is to transition to actual calculated probabilities for occurrence (P_E) and consequence (P_C), and calculated cost impacts (in dollars) for the consequences (C) rather than the numerical factors in Table 2 and Table 3. In this case, schedule delays must be converted to dollars. Currently, there is insufficient information to do this. When the information to do this becomes available, the numerical factors will be replaced with the calculated values.

Assign Risk Level

The risk level is assigned using one of the following two methods:

1. A risk level is assigned automatically by the risk management system. Currently, the risk number ranges in Table 1 are based on a default value of 1.0 for probability of consequence (P_C).

2. A weighting factor is applied in the calculation of the risk level, as shown in Table 2, to give emphasis to risks with high consequence. This weighting factor is used to cause risks with high consequence to rate higher than they otherwise would. Experience has shown that risks with high consequence need to be mitigated (and rated high) even though the probability of occurrence (P_C) is low.

Supporting Risk Analysis Methods

As stated above, alternate analysis and quantification methods are allowed. Typical alternate methods include expert judgment, simulation (e.g., Monte Carlo), and risk or decision trees. These methods are used in project phases when specific analytical or statistical results are desired. This section describes additional risk analysis methods that will be used to support the risk analysis process and provides summaries of some assessments that were employed at the pre-conceptual development stage.

Risk Model and Risk Management System

To facilitate the implementation of the RMP, the NGNP has developed and employed an analytical software tool called the NGNP Risk Management System (RMS). A relational database developed in Microsoft® Access, the RMS provides conventional database utility, including data maintenance, archiving, configuration control, and query ability. Additionally, the tool's design provides a number of unique capabilities specifically designed to facilitate the development and execution of activities outlined in the RMP. Specifically, the RMS provides the capability to establish the risk baseline, document and analyze the risk reduction plan, track the current risk reduction status, organize risks by reference design PASSC, and increase the level of NGNP decision making.

The RMS Hierarchy Viewer provides a rollup/drilldown analysis capability that summarizes quantitative risk scores at various levels of granularity, as shown in Figure 5. The risk scores can be displayed for either the baseline, current status, or the final projected risk. Risks can be rolled up by average or worst case for a selected design configuration. The tool's Hierarchy Viewer also allows the visualization and analyses of the complex relationships between various NGNP project entities (e.g., Critical PASSCs, Risks, Risk Mitigation Tasks, Design Data Needs [DDNs], and Phenomena Identification and Rating Tables [PIRTs]).
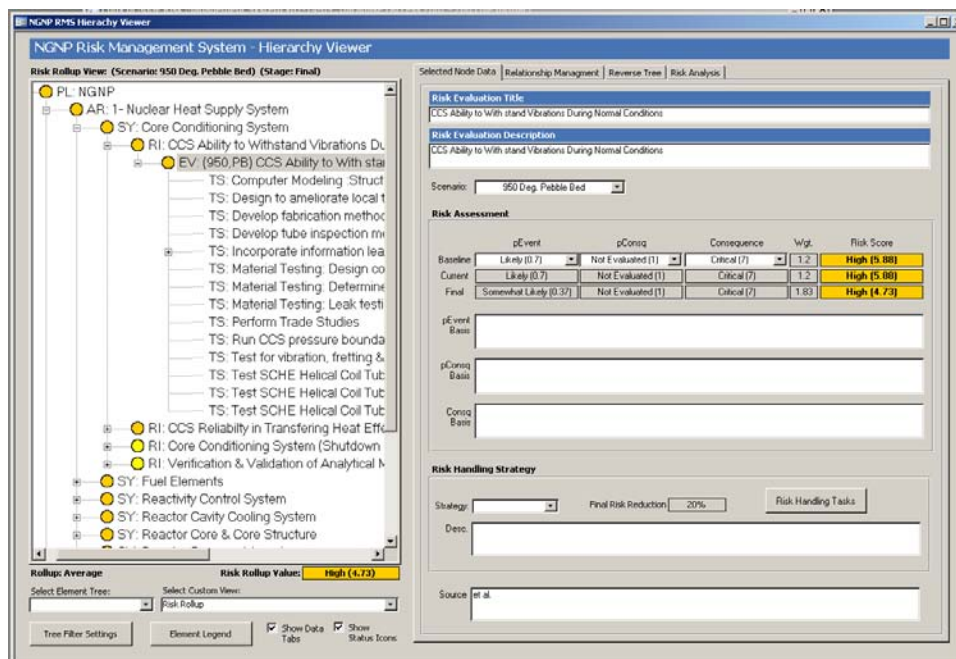

Figure 5. RMS Hierarchy Viewer

The RMS provides the capability to outline and status a risk handling strategy for each identified risk. Risk reduction tasks, which are primarily the tasks needed to advance the TRLs, are assigned to each risk item and the magnitude of risk reduction estimated for each associated task. The status of the risk handling strategy is primarily based on the percent completion of risk reduction tasks. The status of the strategy can also be seen graphically in a Risk Waterfall chart that displays the actual/current risk reduction versus the planned risk reduction over time.

Plan for Risk Reduction

The Project Risk Assessment Tool or PRAT was developed to manage and forecast risk reduction throughout the program. The PRAT was used by NGNP Engineering personnel to evaluate the technical risk associated with deploying each critical system, subsystem or component and determine the risk reduced by performing each task which advances the technical maturity. In other words, in order to reduce the technical risks for the systems of interest, R&D and engineering tasks needed to be performed. To track risk reduction, Systems Engineers created the PRAT to synthesize all the tasks being performed by vendors, scientists and engineers.

The PRAT was necessary because it made it possible for Systems Engineers to map the relationships between tasks and risks for each critical system of the NGNP. Through the PRAT, Systems Engineers were able to visually communicate to project management those risks which were not being addressed and those tasks which did not reduce any risks. This information was crucial especially on a very large and complex project like the NGNP where failure to address all identified risks could impact the safety and licensing of the project when completed. Knowing that it is cost effective to detect and correct problems in the early stages of the system life cycle, the PRAT provided the capability to synthesize all tasks and map them against risk.

Often, the amount of risk reduced by tasks differs from that forecasted which implies that the PRAT matrix will be re-analyzed to verify that the new risk level is commensurate with the current design phase. Measuring and verifying the impact of tasks on risk reduction is a continuous process as the project matures. In Figure 6 below, risks are analyzed to verify that the amount of project risk present at each of the design phases is acceptable.
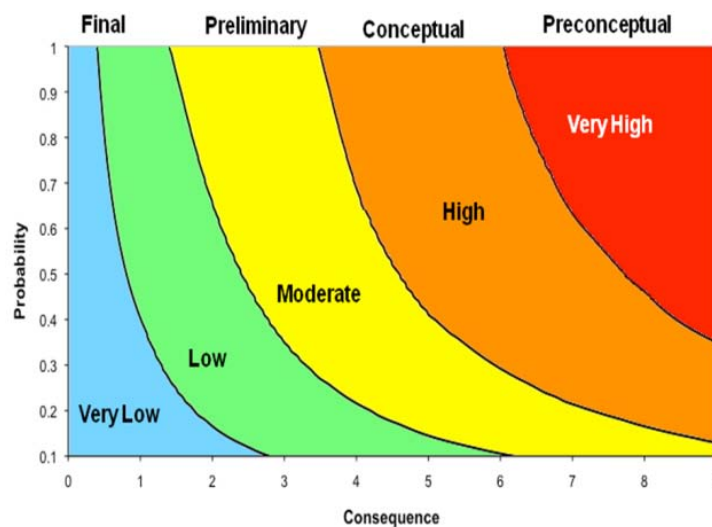

Figure 6. Acceptable project risk present at each of the design phases.

As shown in Figure 6 above, during the preconceptual phase, risks are generally assigned very high prioritization numbers or scores because of the large degree of uncertainty in the early stages of development. A *Very High* risk is highlighted red as shown on both Figures 2 and 3. Figure 3 is the scale for Technology Readiness Level (TRL) of the SSC as it goes through its development phases. As the SSC advances in TRL space, its risk is reduced accordingly. In the final design phase, it is expected that risk is reduced to *Low* and *Very Low* and that the system of interest is ready for commercialization as depicted by TRL 10.

In the PRAT, risk reduction as shown in Figure 2 and Figure 6 are depicted by the "baseline scores" and "risk score after task completion" which is on the left side of the matrix.

How to Read a PRAT Matrix

Risks in Rows. The PRAT is divided into two main areas (Risks and Tasks). The system Risks are shown on the left side of the matrix while the system Tasks are shown in columns perpendicular to the system Risks. In the PRAT matrix, risks are analyzed using a semi-quantitative method involving calculation of a numerical risk number for each event. This risk number is based on a relative numerical value assigned to the likelihood (event probability or PE) that a risk event will occur, the associated impacts of the risk (consequences or C), and the likelihood (PC) that the event will result in the consequence identified. These factors are used to calculate the risk number according to the equation shown in Risk Analysis section above.

Risk numbers are used to prioritize risks and determine the risk level (i.e., very low, low, moderate, high, or very high) of each event. Risk levels are used to tailor appropriate risk-handling strategies, and also define tracking requirements. Levels are defined according to the definitions giving in the Semi-quantitative analysis section above.

The semi-quantitative risk analysis involves the following steps:

1. Determine the probability of occurrence (P_E) for the risk item using criteria in Table 2.

    a. Select the appropriate qualitative descriptor in the risk register, and the associated numerical value is assigned automatically.

    b. Document the basis for the probability of occurrence (P_E) in the risk register with documented results from historical occurrence data, research, tests, comparable applications, or other objective, verifiable means.

2. Determine the probability of consequence (P_C) being realized for the risk item.

    a. As a default, set the probability of consequence to 1.0. If no information is available to discriminate the value when each risk has been or will be realized, leave probability of consequence set to 1.0.

    b. If information is available to discriminate amongst the probabilities of consequence, select the appropriate qualitative descriptor in the risk register, and the numerical value is assigned automatically.

3. Determine the consequence of occurrence (C) for the risk item using the criteria in Table 3.

    a. Select the appropriate qualitative descriptor in the risk register, and the associated numerical value is assigned automatically. If a risk has multiple consequences and

meets criteria in more than one of the ratings blocks, the "worst" consequence should be selected.

    b. Document the basis for the consequence of occurrence (C) rating in the risk register with documented results from historical occurrence data, research, tests, comparable applications, or other objective, verifiable means. At a minimum, this should include a justification or rationale for the rating and whether it applies for the duration of all project phases or for the activity being assessed.

4. Assign a unique risk number

5. Document the basis and rationale for each risk determination

Tasks in Columns. The matrix overlays the risks against the tasks designed to advance technology maturity and reduce risk, and the anticipated amount of risk reduction is forecasted for each task. Some tasks reduce several different risks and this depicted by the bar charts on the bottom of the matrix which depict the impact each task has on all the risks for particular SSC. Using the matrix for risk-informed prioritization, these tasks will rate higher than others.

Each task was evaluated, and the task's impact on risk reduction is recorded in the body of the matrix. As will be seen on the PRAT, the impact of certain tasks exceeded other tasks and there were some tasks being performed which did not reduce any risk. To assign the percent impact of a Task on risk reduction, a semi-quantitative process was adapted. This process required collaboration of SMEs to quantify the impact of the tasks being performed on each risk.

The semi-quantitative process involves the following steps:

1. Prioritize each task in relation to its ability to reduce a particular risk.

2. Determine if a combination of probability of occurrence (P_E), probability of consequence (P_C), and the consequence (C) affects the baseline risk prioritization number (risk score) of each risk.

3. Assign percent impact of each prioritized task on risk.

4. Document the basis for each scoring.

Semi-Quantitative Analysis. The center of the PRAT matrix uses the same semi-quantitative analysis as document previous in this paper to quantify risk reduction as a product of task performance. Changes in the resulting risk score are shown in the bars on the right of the matrix.

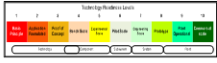Figures 7 shows the PRAT matrix for one of the critical NGNP PASSCs.

Figure 7. PRAT matrix for the Reactor Pressure Vessel

Conclusion on Risk Management

Through a disciplined approach, the NGNP Project has been able to apply various risk management techniques and tools to forecast effective risk reduction for the project. As various project tasks are completed, the risk management system provides feedback and forecasting on the effective risk reductions performed. By managing the risks is an automated, relational database, the NGNP Project is providing excellent risk data to all stakeholders and decision makers associated with the project.

Disclaimer

Biography

John M. Beck II works at Idaho National Laboratory as a Systems Engineer on the Next Generation Nuclear Plant Project. He has been actively involved in applying systems engineering principles to a variety of projects during his career. He has experience in numerous areas of systems engineering including systems architecture, interface analysis, functional analysis, requirements management, risk analysis, technology readiness assessment, and technology

roadmapping. John has a B.S. from the University of Utah and a M.S. in Systems Engineering from the University of Idaho. He is a member of INCOSE and a former local INCOSE chapter secretary.

Harold J. Heydt has worked as a Nuclear Safety Research Engineer, a Technical Planning Specialist, the Value Engineering Program Lead, and an Industrial Engineer. He practices in the areas of Systems Dynamics, Human Systems Integration, Value Engineering, and Facilitation. He is a researcher/practitioner in the area of multi-disciplinary problem identification for 25 years. Areas of interest include Process and Organizational Effectiveness, Ethical Group Model Building to obtain Informed Consent, Systems Thinking, and Qualitative/Quantitative Problem Formulation. Harold has a BE from Stevens Institute of Technology, a MS in Mechanical Engineering from New Mexico State University and a MESE from the University of Idaho.

Emmanuel O. Opare. Emmanuel received a B.S in Mechanical Engineering from Brigham Young University-Idaho and has working experience in Venture Capital, Entrepreneurship, Manufacturing and Systems Engineering. Currently a Systems Engineer at the Idaho National Lab, he supports the Next Generation Nuclear Plant (NGNP) project with Systems Engineering activities like Risk Management and Analysis, Requirements Management and RAMI Analysis.

Emmanuel is the author of the PRAT model- the decision support tool for Risk Analysis and a member of American Society of Quality Engineers (ASQ) and INCOSE. Emmanuel is an engineer and a sculptor and has research interests in strategic management, operational research, resilience, system reliability and adaptation of biological designs to physical systems (Biomimicry/Biometics).

Kyle B. Oswald received a B.S. Degree in Mechanical Engineering from Brigham Young University and an M.S. Degree in Mechanical Engineering from the University of Idaho. He is currently a Systems Engineer at the Idaho National Laboratory (INL) where he has worked for nearly 19 years. He is an expert in the development and application of advanced systems engineering models and tools. These tools employ numerous systems engineering technologies including: requirements management and traceability, multi-attribute utility theory, capability assessment, trades analyses and system of systems design.

Contact Information

Idaho National Laboratory, 2525 N. Fremont Ave., Idaho Falls, ID, 83415; Tel: 208-526-4248; Fax: 208-526-4313; Email: john.beck@inl.gov