RISK REDUCTION IN NUCLEAR FACILITY DEACTIVATION – DECOMMISSIONING & RESTORATION (DD&R): A SYSTEMS ENGINEERED APPROACH

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ABSTRACT

The basic elements of Deactivation, Decommissioning and Restoration (DD&R) are Characterization, Licensee Documentation, Integrated Safety Management, Management Planning and Procedures, Worker Training and Construction Execution, Nuclear Conduct of Operations, and Integrated Waste Management. With increased pressure to accelerate and streamline project execution, an increased emphasis is needed for risk reduction, graded technical and programmatic approach, and state of the art risk analysis.

The systems engineered approach to risk reduction allows owner, contractor, regulatory authorities and stakeholders to make, analyze, and document critical choices that impact DD&R projects. Stakeholder site-wide collaboration and assessment of risk needs more refined development to access, plan and establish performance milestones and deliverables for project acceleration and stakeholder satisfaction within project end state requirements.

This paper addresses the systems engineered approach to access and plan risk reduction. The systems engineered approach deals with key criteria and methodology for a systematic approach, analysis and monetization for risk reduction. These key criteria and methodology for risk analysis and reduction will further focus all stakeholders on issues and choices that result in safer, accelerated DD&R projects. The systems engineered approach builds consensus for risk reduction methodology as well as documents planning and closure implementation. Discipline in risk based initiatives drives projects to faster, more efficient project end state closure.

INTRODUCTION

When approaching the DD&R of a nuclear facility, Characterization, Licensee Documentation, Integrated Safety Management, Management Planning and Procedures, Nuclear Conduct of Operations, and Integrated Waste Management are typically addressed.

The DD&R activity includes planning, organizing, execution, performance metric monitoring and project course correction, if required. Forty percent of DD&R project scope deal with waste management and the back-end of the fuel cycle. The systems engineered approach for specific execution for waste disposition alternatives and its related risk factors affecting DD&R projects is addressed [1].

Industry today accelerates cleanup and streamlines DD&R project duration. With this acceleration, emphasis has been placed on risk reduction and application of a graded approach to project acceleration, as well as prioritization of events that reduces overall risk to the

stakeholders. Some past projects have minimized discipline in establishing plans, related risk, and associated stakeholder issues. This resulted in missed milestones and added cost and schedule to the projects. A systems engineered approach and methodology is needed to process and document critical choices to optimize cost and schedule effectiveness in project execution. This optimization of risk reduction processes includes analysis and acceptance by the owner, contractor, regulatory authorities and general public - *the stakeholders*.

Risk reduction is a complex issue that combines physical measurement as well as social, both actual and perceived. Risk reduction typically has had numerous interpretations and opinions, based on the view of the stakeholder. Risk reduction for DD&R is *minimizing environmental, financial and social impact to stakeholders through the systematic assessment, planning, safe execution, and delivery of restoration commitments for DD&R projects strictly compliant to regulatory mandate, industry standard of care and continuous application of proven innovation.*

It is this stakeholder collaboration and assessment of risk that requires further development to access, plan, and establish performance milestones and deliverables for project acceleration and stakeholder satisfaction aimed at the project end state.

Table I depicts the areas of risk, balanced against the various project phases of a DD&R program. One might inquire why risk reduction is important in DD&R planning and execution. The answer is it allows effective prioritization of critical resources, minimizes stakeholder impact, and provides lessons learned that can be integrated in DD&R projects as well as future Life Cycle Planning and budgeting for future nuclear program development. It additionally allows evaluation for choices that are within the regulatory framework, which may be stakeholder specific for the vision of the site end state.

Systematic risk reduction that is currently being used in DD&R programs should additionally be integrated in future nuclear facility development, research program planning, and future life cycle facility analysis. These lessons learned as well as the ultimate high level waste repository endorsement and operation should be directed to future energy program policy, planning, and development.

Table I. Area of Risk Impact for a DD&R Program

Areas of Risk Impact	Nuclear Facility DD&R Project Elements				
	Planning / Assessment	**Admin**	**Program Execution**	**Technical Execution**	**Contractual**
Environmental	♦ End State Assessment and Concurrence	♦ Record of Decision / Reclamation Plan Acceptance	♦ ISMS ♦ Compliance to Reg.	♦ Low Incident ♦ Compliance ♦ Effective ES&H Solutions	♦ End State Compliance
Financial	♦ DD&R Funding ♦ Legacy Funding	♦ Treasury Operations ♦ Insurance Funds & Guarantees	♦ Schedule Compliance ♦ Sound Bus Practices	♦ Cost Efficiency ♦ Efficient Life Cycle Cost Expenditures	♦ Contract Compliance ♦ Completion on Schedule and within Budget
Social	♦ Regulatory / Political Enforcement	♦ Compliance Agreements ♦ Workforce Jurisdictional Compliance	♦ Workforce Transition ♦ Stakeholder Progressing	♦ Compliance to End State Requirements	♦ End State Acceptance Release of Site ♦ (NFA)

SYSTEMS ENGINEERED APPROACH TO RISK REDUCTION

The systems engineered approach is a detailed process that starts with objectives and ends with DD&R end states. The detailed process works through the key areas of Environmental, Financial, and Social needs and solutions accounting for project deliverables, metrics, probability, consequence and occurrence of deliverables, as well as a documentation to allow stakeholders to make informed decisions relative to outcome and end state.

The risk management process includes a number of systematic process steps:

- Defining the context and risk management criteria
- Identification of the various risk scenarios
- Assessment of the significance of the individual risks
- Identification and implementation of risk mitigation steps
- Monitoring, reviewing and taking necessary corrective action for deviations.

The systems engineered approach addresses key criteria and methodology to reduce project execution risk. Included is:

- Owner Commitments and Issues
- Project Performance

- Project Conduct of Operations Standards
- Project Safety
- Regulatory Requirements
- Stakeholder needs and assurances
- Financial
  - Project Issues
  - Owner / Licensee Financial Issues
  - Contractor Financial Issues
  - Insurer / Bonding Issues
- Project Contract Methodology
- End States that take the various risk management issues into consideration
- Workforce Jurisdiction
- Workforce Transition
- Legacy Management and Economic re-development

Figure 1 [2] addresses a systematic overview of the risk management process, as most practitioners would apply today. Table II lists key issues to consider in a DD&R Project in managing project risk and applying risk reduction techniques. Table III [3] lists a typical DD&R Program at a nuclear site in which the key risk factors, qualitative evaluation of risk scenarios, probability of occurrence and respective mitigation analysis is summarized.

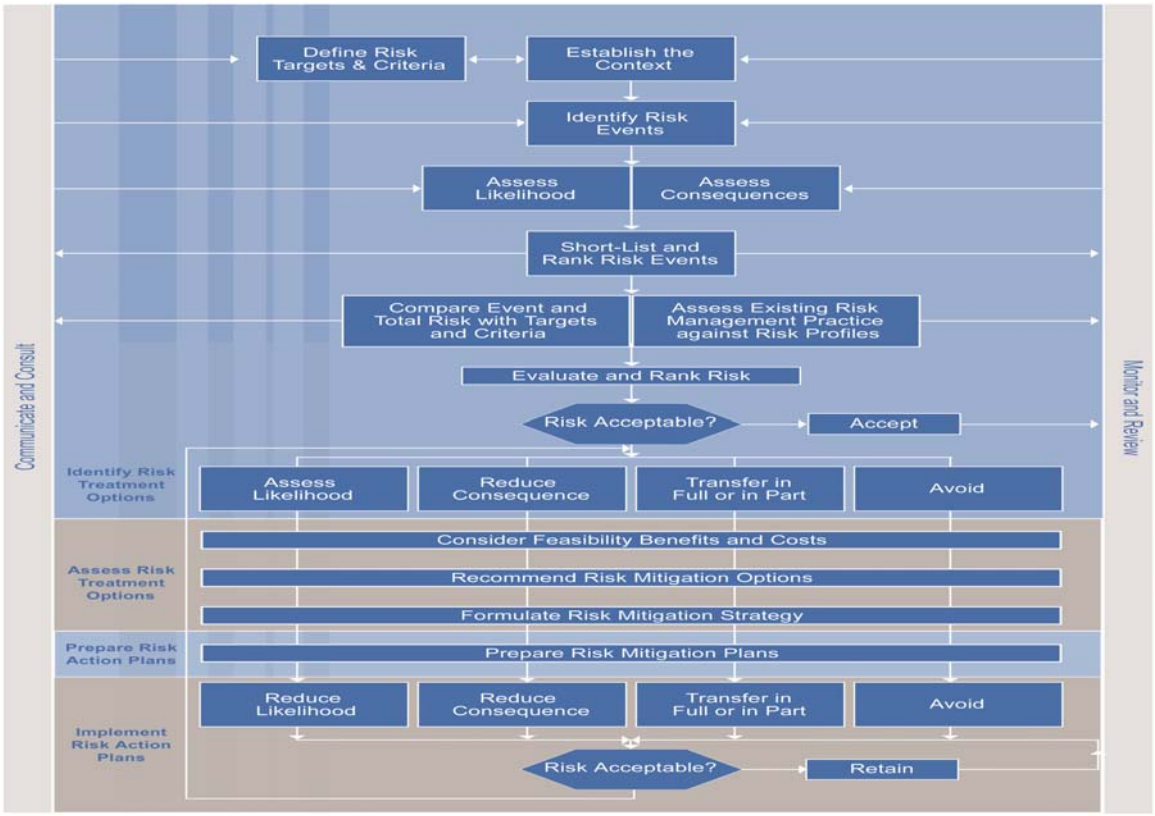

Fig. 1. Overview of Risk Management Process.

Table II. Issues to access and plan risk reduction as applied to DD&R.

Execution	Demonstrated experience and methodology D&D and /or Restoration
	Safe execution; Project Safety Mandates
	Owner Commitments and Issues
	Key criteria, innovation and methodology for a systematic approach to risk reduction
	Project Strategy and Performance Objectives
	Project Conduct of Operations Standards (graded Approach)
	Facility Conduct of Operations
	Incidents
	Corporate / Management Accountability
	Workforce Jurisdiction
Regulatory	Compliance to regulations
	Compliance to Record of Decision
	Compliance to Site-wide agreements that lead to end state compliance / no further actions
Stakeholder	Clear understanding of Site End Use requirements
	Clarity as to level of Clean-up standard and requirements for No Further Actions
	Clarity and In-place agreements for disposal, transportation and current environmental impact assessment and approvals
	Clear Directives from stakeholders for Legacy and Long Term Stewardship Operations
	Transportation
	Workforce Transition
Contract Methodology	Owner Self Perform- Owner has all open ended financial and execution liability in addition to legal / regulatory accountability for the restoration.
	Owner manages the work / Contractor executes some or all of the work. Owner has all open ended financial and execution liability in addition to legal / regulatory accountability for the restoration
	Performance award fee Project Contracting- Owner manages the contract / contractor manages the work.
	Owner transfers the specific project financial and execution liability to a Contractor for all known characterization for end state requirements in addition to legal / regulatory accountability for the restoration
	Performance Based Contracting (Guaranteed Fixed Price Project Contracting)- Owner transfers the open ended financial and execution liability to a Contractor for a specific project restoration while still retaining legal / regulatory accountability for the restoration (could include cost cap)
	Asset Liability Transfer –Owner transfers the open ended financial and execution liability to a Contractor while still retaining legal / regulatory accountability for the restoration (could include cost cap, warranty, and re-opener guarantees)
Financial	Contract Requirements, Project Incentives / Penalties; Regulatory Penalties and Fines
	Incentives to maintain a level of safety
	Owner / Licensee Financial Issues
	Contractor Financial Issues
	Insurer / Bonding Issues
	Community Redevelopment Financial Impacts

Table III. Anonymous Nuclear Facility DD&R Risk Analysis

Risk Uncertainty	Risk Event Description	Category Legend (Note 1)	Pre-Mitigate Prob-Severity	Consequences	Mitigation Actions	Post Mitigate Prob-Severity
WASTE MANAGEMENT						
High Concentration-Uranium; No disposition Pathway for MW	Some waste is found to have no immediate disposition strategy.	F, S, P	High / High	Waste shipments delayed, increased treatment, repacking, and long term storage	ID questionable waste packages, ID	High / Medium
Inaccurate Characterization Data	Incomplete or inaccurate analytical data found	F, S, P	High / Medium	Cannot ship, must re-characterize	Audit during transition, add cost and schedule contingency	Medium / Low
Disposal Site change in WAC	TSDF changes WAC due to Reg. Opr Lic. Chg.	F, S, P	Medium / Medium	Delay shipment, more sampling, possible re-packaging	Keep close contracts with TSDF, Follow F.R for changes	Low/ Low
More Waste than in SOW	Inventory larger than previously thought	F, S, P	High / High	Would increase cost and time	Spell out assumptions	High / Low
Transition delays WM Disposition	Delay prevents smooth transition from PREVIOUS CONTRACT	F, S, P	Low / Medium	Near term deliverables delayed	Identify key causative events	Low / Low
Characterize to ship strategy; not acceptable	Minimum data points found insufficient for disposition. More characterization required.	F, S, P	Medium / Medium	Increased costs	Group wastes into populations for cost / benefit analyses.	Low / Low
Prohibited item found in waste package	Prohibited or excessive quantity	F, S, P	High / High	Violation of requirements	Concerted effort to ID / review 100%	High / Low
REGULATORY & SAFETY ISSUES						
Change in end state clean-up standard		F, S, P, R	Low / High	Increased scope of work	Clearly state Rqmts.	Low / Medium
Serious Injury / Fatality	Emp. injured or contaminated	F, S, Sf	Low / High	Safety review / shutdown / R fee	Planning / procedures	Low / Medium
Impact of Safety Order	Codifying ISMS into regs. Civil Penalties	F, S, Sf, St	High / Medium	Additional documentation Rqd.	Complete ISMS	High / Low
Delays in Regulatory Approval		F, S, P	Medium / Medium	Processing / shipping delays	Est. Sched. contingencies	Medium / Low
Change in Reg.		F, S, P	Low / High	Additional reviews / audits	Proactive safety / compliance	Low / Low
LABOR RELATIONS / HR						

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Risk Uncertainty	Risk Event Description	Category Legend (Note 1)	Pre-Mitigate Prob-Severity	Consequences	Mitigation Actions	Post Mitigate Prob-Severity
Workforce Jurisdiction Issues	Union versus non-union	F, S, P	High / Medium	Increase cost / delay completion	Establish a Labor agreement	Medium / Medium
Labor Work Stoppage	Unionized labor stops or slows work as group	F, S, P	Low / Medium	Could miss key milestones	Meet Unions / Incentives	Low / Low
Bumping	Unionized labor practice of bumping	F, S, P	High / Low	Confusion. Retraining, slowdown	Develop seniority Sys w/Union	Medium / Low
Jurisdictional work stoppage	Union workforce strike	F, S, P	High / low	Not meeting schedule / bad PR	Seek Union analysis	Medium / Low
Lack of workforce support	Production slowed w/o Tech or Process Reason	F, S, P	Low / High	Delay in scheduled activities	Meet Unions / find source	Low / Medium
SECURITY						
Dirty Bomb; Terrorism	Terrorist attack using a "dirty bomb"	F, S, P, Sf, St	Low / High	Pers. Injury, Prop. Damage, etc.	Know risks / protect key targets	Low / Medium
Increase in security Requirements	National security level is increased	F, S, P	High / Medium	Incr. searches / time to access	Alert Pers to issue and plan	High / Low
Delay in getting clearances	Clearances take more time than normal	F, S, P	High / Medium	Escorts / decreased Info. access	Submit Appl. ASAP	High / Low
Loss of classified information	Classified information lost or stolen	F, S, P, Sf, St	Low / High	National Security investigation	Pers. Training and a CMCS	Low / Medium

(Note 1) Category Legend - Financial, Regulatory, Performance / Technology, Schedule, Safety, Stakeholder

The benefit of the systems engineered approach is to articulate the risk reduction objectives, the potential impediments and the mitigation required to ensure risk issues are manageable throughout the DD&R effort. The process provides a systematic application of management policies, site related procedures, processes and consistent project procedures to identify, analyze, assess, treat and monitor the risk factors and trends. The various participants in such a Systematic Risk Evaluation include Stakeholders as noted in Figure 2. The participants include:

- Project staff
- Client / Agency Representatives
- Regulatory Staff
- Subject matter experts
- Local Stakeholders
- Risk Analysts
- Insurer Representatives

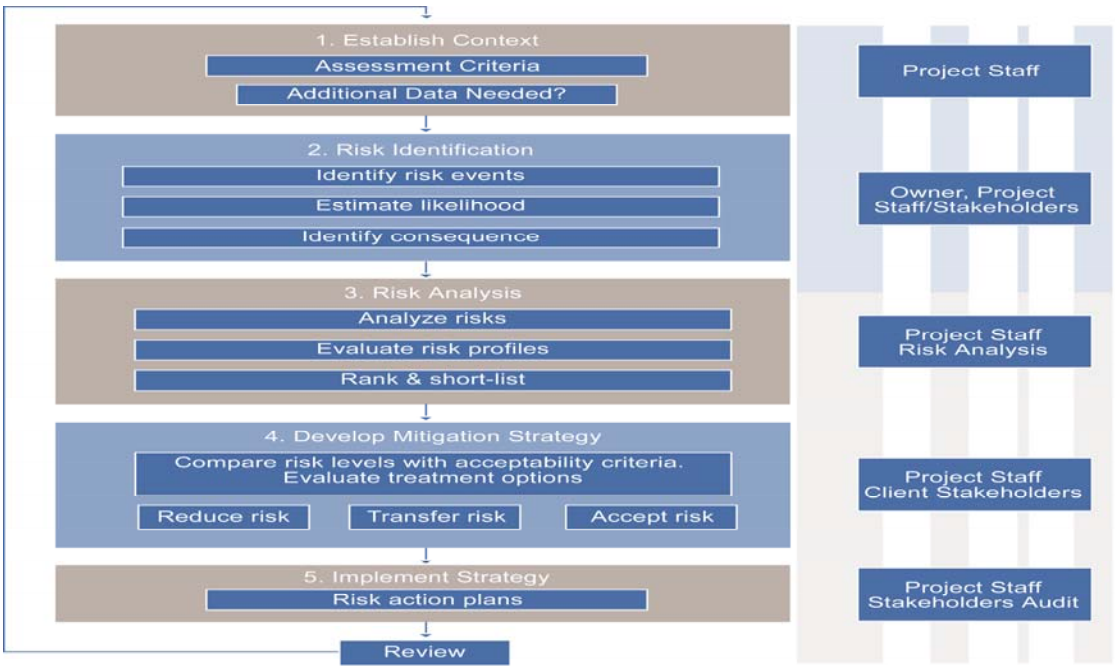

Fig. 2. Process flow for roles of stakeholders.

The analysis speaks to key responsibilities for the parties involved to ensure adequacy and correctness; as well as to provide a systematic path forward that communicates and documents results. The consequence for not entering in a in-depth analysis and commitment could include cost for penalties, fines, liability, default of agreements, civil claims, legal issues, natural resource disasters, adverse publicity, stakeholder dissatisfaction and distrust, loss of worker morale, increased insurance risk, increased finance costs, and possible revocation of licenses.

Dealing with the analysis and treatment of risk factors includes recognition of issues (real and perceived) as well as execution of mitigation techniques for reduction of risk impact. Figure 3 [3], Risk and Uncertainty Tools, pictorially depicts fundamental risk and uncertainty analysis tools to identify and establish probability of occurrence for potential events with respective impact. The classical “*Pareto*” distribution and the Probability Density Function (PDF) deals with the identification; the impact of acceptable versus unacceptable events used in charting the event and the probability analysis of an event happening within a certain certainty (confidence level).

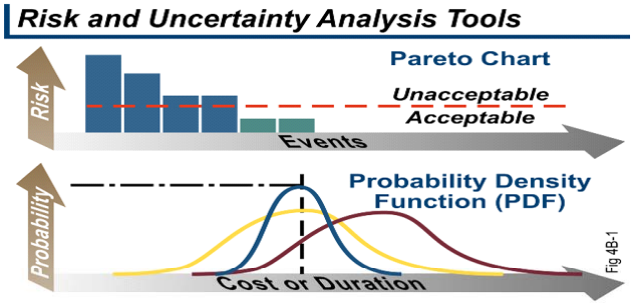

Fig. 3. Risk and Uncertainty analysis tools.

Risk Analysis identifies all risk ‘Events’ and establishes the potential probability and impact for each. ‘Events’ are ranked by combining probability and impact severity into an overall “Risk” score. Charting risk scores and events, allows selection of Risks warranting further analysis. Uncertainty Analysis uses optimistic and pessimistic cost and duration estimates as input for simulation. The outputs of this analysis are cost and schedule PDFs. The PDF is charted to identify critical and near critical paths, thus enabling a focus of resources to reduce cost, duration and uncertainties for key activities. By synthesizing ‘Risk’ and ‘Uncertainty’ analysis, Statement of Work uncertainties are identified, mitigation methodology determined, and cost risk monetized. Typically the modeling used is a Monte Carlo distribution.

As noted in Figure 4 [3], these events are:

- Analyzed against performance targets
- Prioritized
- Evaluated with the mitigation in mind
- Monetized
- Tracked and course corrected as required

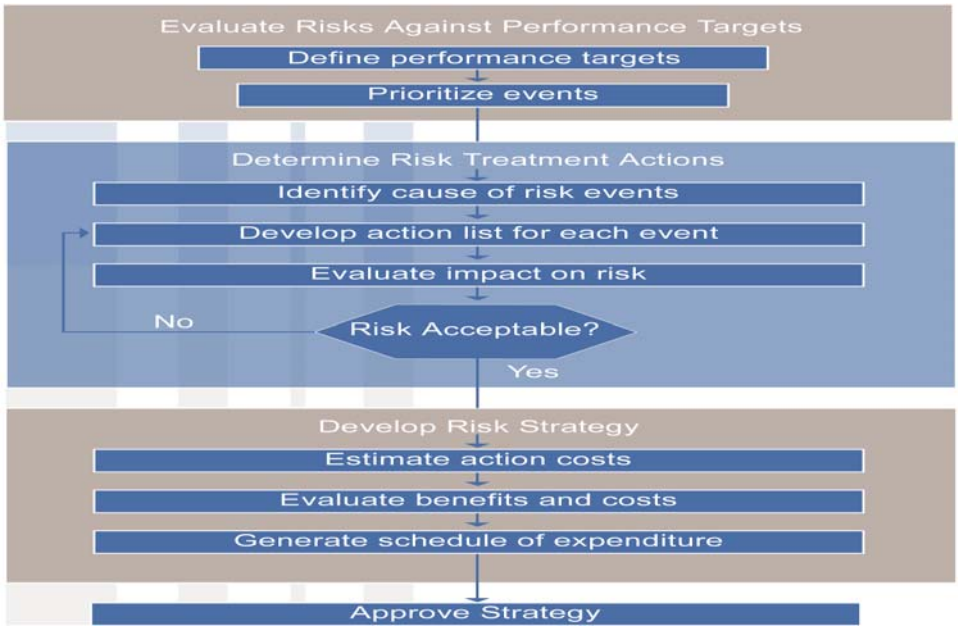

Fig. 4. Evaluation of Risk Events against Performance Targets.

Key to a realistic risk modeling is to qualitatively and quantitatively evaluate and document risk events, probability of occurrence, program mitigation or “work around,” and the respective confidence levels acceptable for all stakeholders involved. Figure 5 exemplifies a restoration project for a mining reclamation operable unit in which a Monte Carlo analysis with an 80 percent confidence based on 2000 computer trials depicts the range of cost for the restoration [4]. Systematic analysis dictates that budgeting of this activity for an 80 percent confidence shows a budget for $2.6 Million. The confidence is based on the qualitative scenarios: the level of subject

matter expertise and the buy in from stakeholders to assure that the remedies are compliant, acceptable and require no further action.

The key result of the process is to monetize each risk scenario and establish the confidence level of the monetized risk factor. With the factor monetized, realistic baseline schedules and costs are established for the DD&R Project. As the project progresses, the risk factors are tracked, modified and re-baselined on a periodic basis (minimum quarterly timeframe). This systems engineered approach and implementation is required for more accurate program management and project forecasting.

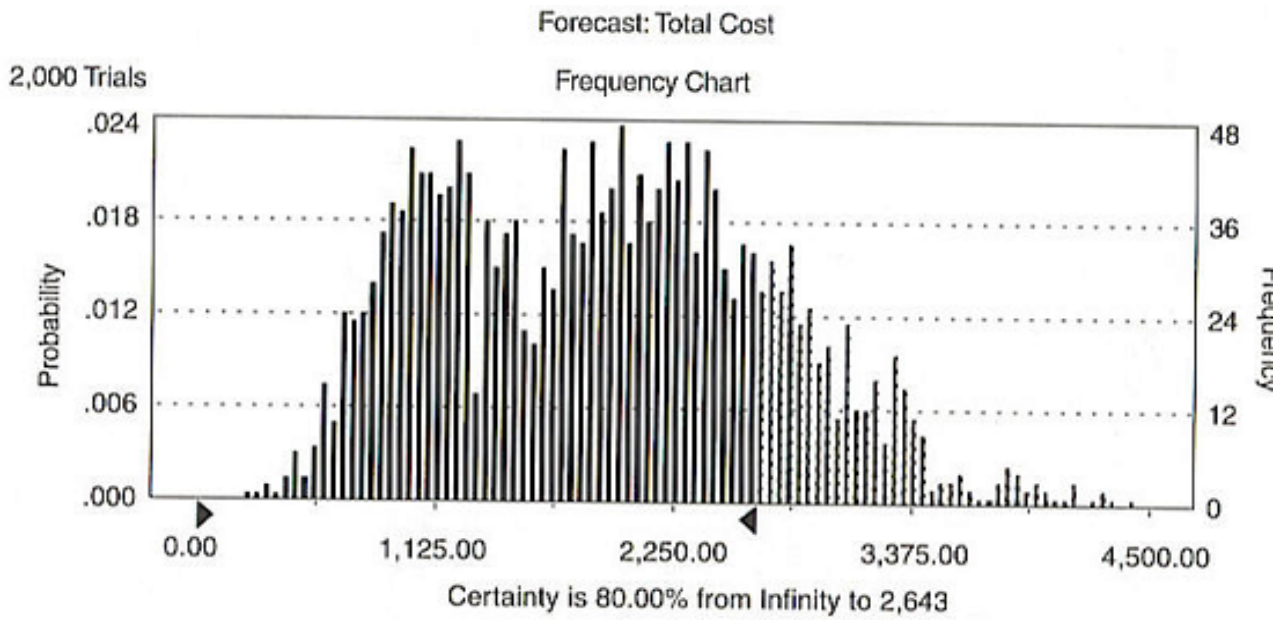

Fig. 5. Forecast of Cost for an Operable Unit Reclamation with 80% confidence applied.

The ultimate system engineer approach to risk reduction is to bond the entire stakeholder group with the end state in mind; establishing the DD&R road map and the systematic risk reduction strategy. Figure 6, Risk Reduction System Integration and Management Process briefly outlines the systems engineered approach that is needed for DD&R activity. This process should be continually refined and integrated as well as standardized into current and future DD&R activities; providing continuous improvement and lesson learned throughout program implementation.

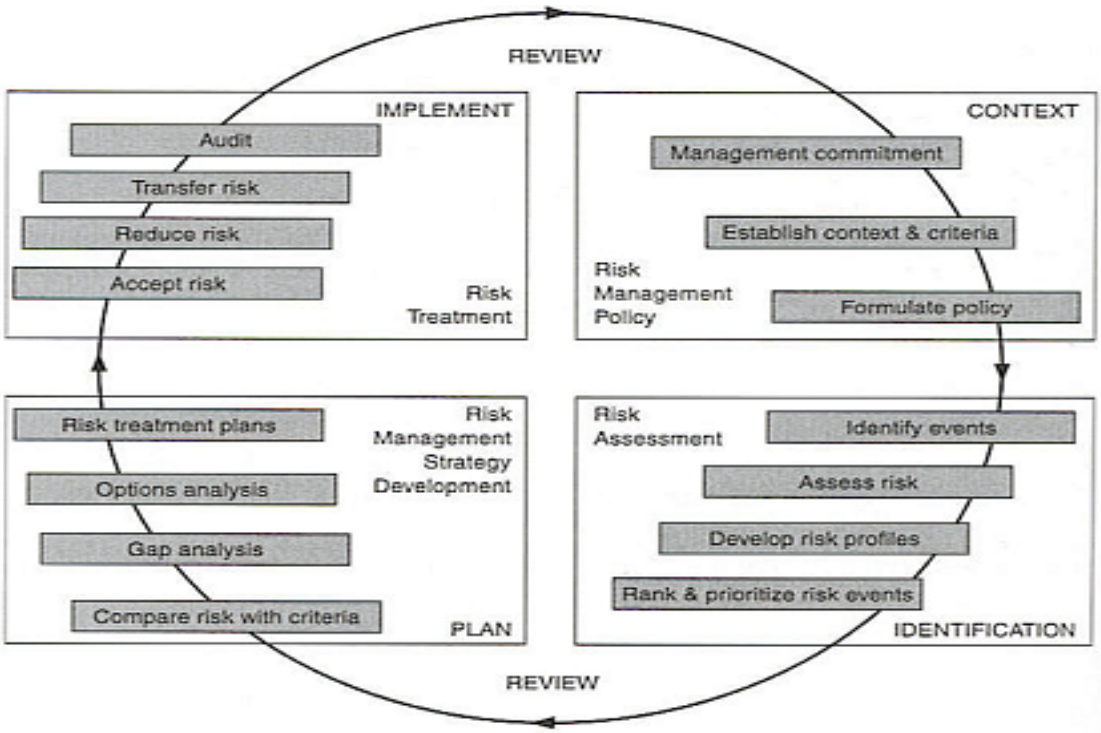

Fig. 6. Risk Reduction System Integration and Management Process.

SUMMARY

DD&R Projects are complex, technically and programmatically challenged and require significant social involvement. The three legged stool of risk reduction: environmental, financial and social mandates a systems engineered approach to access, plan, execute, track and steer risk reduction for DD&R Projects. It includes the demonstrated experience and methodology needed for safe execution and compliance to criteria as applied for various DD&R project types; research reactor, nuclear generating, and federal production facility closures that lead to end state compliance / no further actions.

These key areas of focus influence criteria and methodology for risk analysis and reduction. The systems engineered approach builds consensus for risk reduction methodology as well as documents planning and closure implementation. Discipline in risk based initiatives drives project restoration to faster, more efficient project end state closure.

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