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Nuclear Mega Project
Risk Analysis Model

Oak Ridge Tennessee
November 5, 2009

Content

- Objectives
- Risk Assessment Approach
- Nuclear Risk Assessment Model Overview
- Lessons Learned

Objectives

- Present a new approach to analyzing risks of large and complex projects that may be directly applied to DOE
- Discuss an example of how this methodology was recently used in a nuclear project, and how this can fit DOE's unique challenges
- Present the benefits of using a risk assessment for protecting the government's interests and reduce risk exposure

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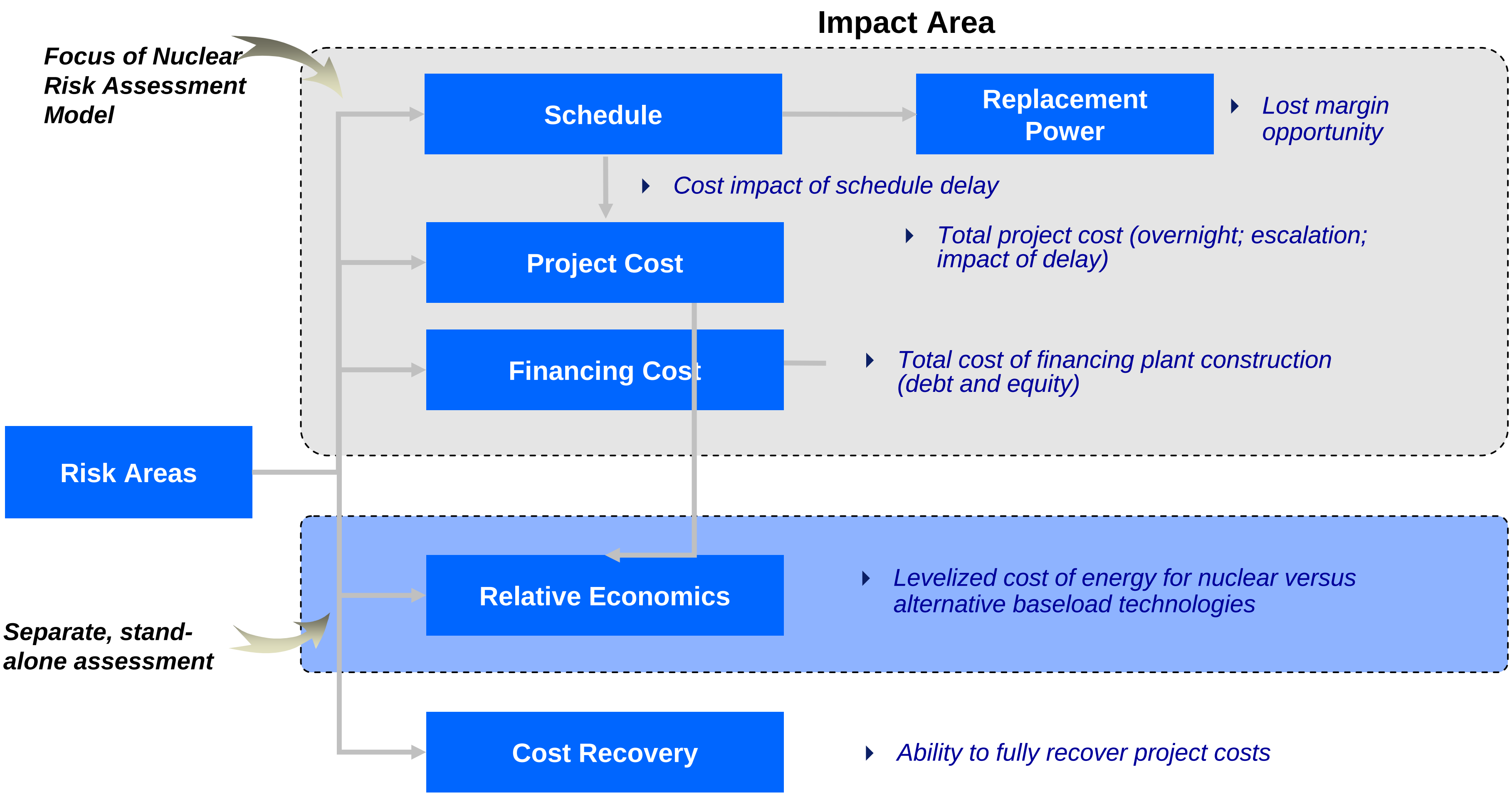
Approach to risk assessment follows a logical progression of risk identification, impact, and mitigation analysis

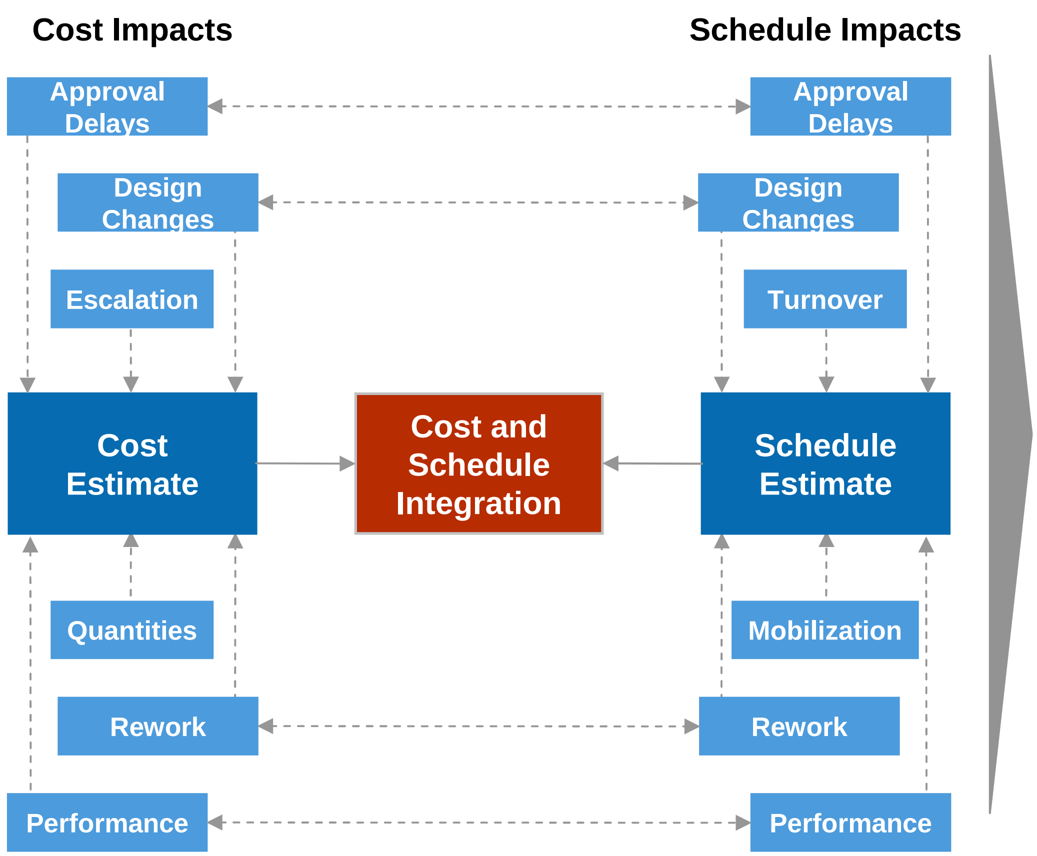
Project Stages	*Risk Identification*	*Risk Analysis*	*Risk Mitigation*	*Life Cycle Maintenance*
Purpose	**Capture relevant risks**	**Quantify impact of risk**	**Minimize risk impact on project**	**Update outputs as project evolves**
Key Tasks	▪ Develop views on risk causation ▪ Identify all "root causes" of risk and corresponding cost and schedule impacts ▪ Map risks to project tasks, escalation rates, and/or cost elements	▪ Analyze underlying risk causations ▪ Assess root cause likelihood ▪ Estimate individual cost and schedule risk impacts ▪ Run pre-mitigation Monte Carlo simulation	▪ Develop view of overall project impacts ▪ Identify risks with most significant impact on project cost and schedule ▪ Develop mitigation strategies ▪ Run post-mitigation Monte Carlo simulation	▪ Develop customized reports ▪ Develop and update maintenance process ▪ Update Model and inputs as events, both internal and external to project, arise
Products	**Preliminary Risk Register**	**Distributions of Cost and PCD**	**Risk Mitigation Strategies**	**Risk Analysis Model**

The core of the risk assessment approach is the Nuclear Risk Assessment (NRA) Model



The NRA Model captures the complex inter-relationships among risks and their ultimate impact on schedule and costs

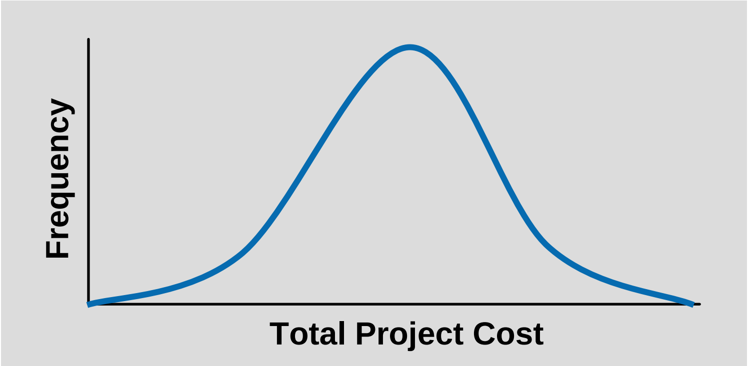
Illustrative Risk Alignment



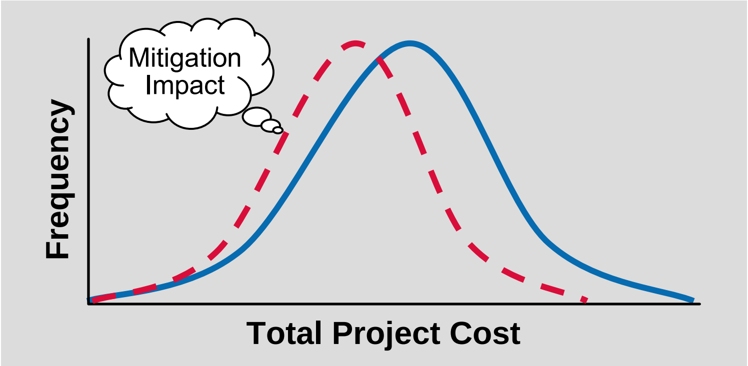
- Timing of risk occurrence is addressed through detailed WBS and schedule alignment
- By definition, each risk has three basic components:
  - A root cause
  - A probability (or likelihood) of the cause giving rise to a specific impact (or range of impacts)
  - A potential, future impact, or consequence
- There are two distinct types of impacts modeled in the assessment
  - Risks having less than a 100% chance of occurring
  - Uncertainties around quantity and price assumptions are not associated with a probability and have a continuous impact distribution for all iterations

The risk model, and accompanying analysis, focuses on quantifying risk and uncertainty - and impacts of mitigation

Pre-Mitigation Impact Distribution



Post-Mitigation Impact Distribution

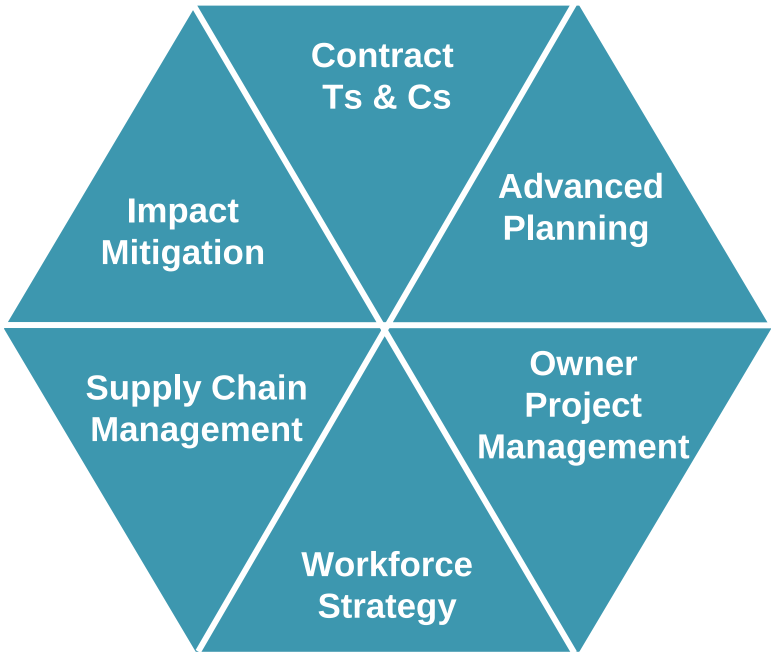


Purpose of the Mitigation View

- Understand the range of possible mitigating actions – by key risk element
- Determine the individual and collective impacts of mitigating actions
- Define appropriate scenarios and combinations of mitigating actions
- Provide for an ongoing framework and capability to assess risk mitigation

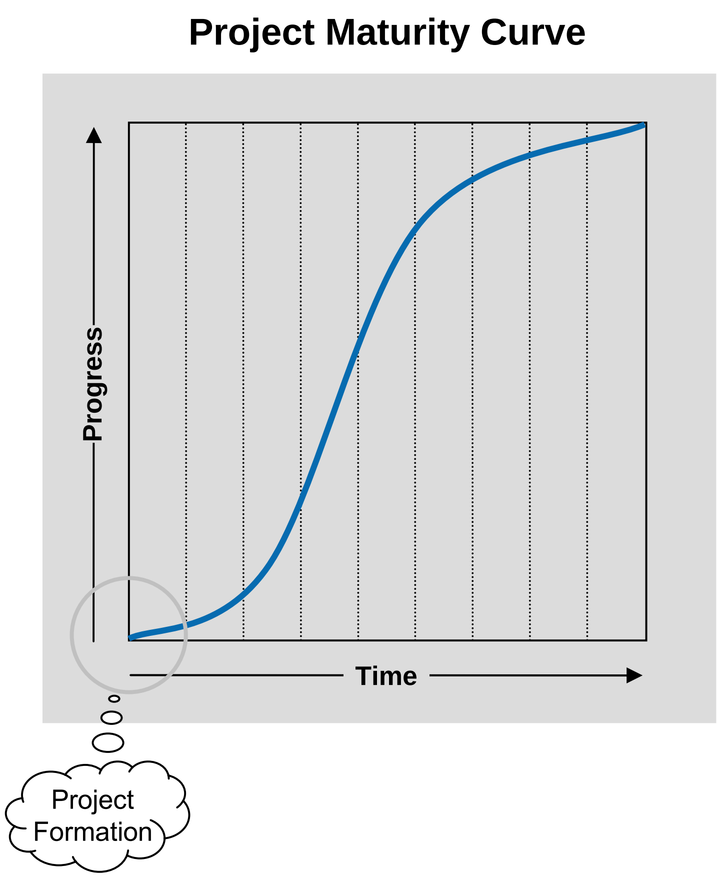
A range of potential risk prevention and mitigation activities are considered for individual risks

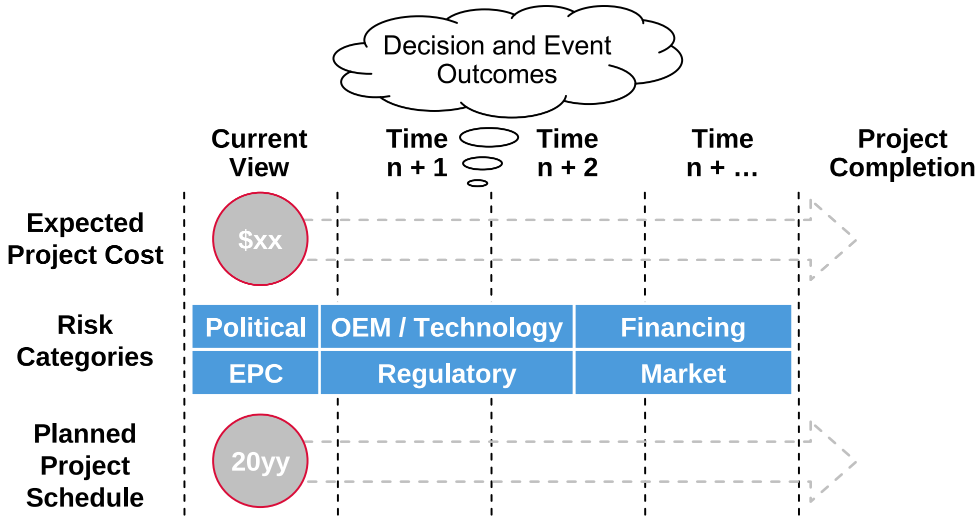
Risk Prevention and Mitigation Categories



Description
▪ **Contract Ts & Cs:** Contractual terms that provide the appropriate incentives / penalties for contractor performance, allocate risks in the most effective manner, and allow owners to have the necessary project oversight ▪ **Advanced Planning:** Detailed planning activities aimed at identifying and resolving issues that could impact schedule and costs (e.g., extensive construction planning) ▪ **Owner Project Management:** Ensuring availability of deep project management capabilities and performance metrics that allow the owner to provide active oversight of project activities ▪ **Workforce Strategy:** Activities which allow the development and retention of the needed pool of skilled resources (technical and craft) ▪ **Supply Chain Management:** Direct involvement in selecting, monitoring, and evaluating supplier performance ▪ **Impact Mitigation:** Activities that may lessen the severity of the impact in the event a risk does occur

The model was developed to reflect a current view of potential outcomes and be updated as events evolve





- Initial views may be based on a preliminary estimate reflecting a low degree of engineering completion
  - Underlying logic for planning and execution would reflect an initial perspective on scope, roles and performance levels
  - Cost and schedule elements individually subject to changes in unit and factor costs
- Nature of DOE EM projects requires a model that can be updated effectvely

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The core of the risk model is a cash flow projection that uses Monte Carlo simulation to integrate cost and schedule risks

Simplified Model Architecture

Risk Register

- Root cause
- Likelihood of occurrence
- Impact type (cost, schedule, relative economics, and/or cost recovery)
- WBS element, cost element, and/or escalation rate impacted
- Impact range (across triangular or normal distribution)

The risk register contains risks associated with nuclear plant construction and defines how they impact the project cost and/or schedule

Likelihood of occurrence and impact data are included from both a pre- and post-mitigation perspective

Project Schedule[1]

- Task start date
- Task duration - dynamically linked to schedule risks
- Task dependencies (driving critical path)

Task start date, duration, and dependencies interact to determine end dates and critical path

Cost Estimate

- Vendor & owner costs distributed across schedule tasks and broken down by cost factor
- Costs adjustable for uncertainty and cost risks

Real dollar cost estimates referred to as 'cost basis' (by schedule task)

Cash Flow Projection

- By schedule task and year
- Dynamic to capture quantity estimate uncertainty and cost and schedule risks
- Reports total nominal project costs through completion date, financing costs, and lost margin opportunity / replacement power

Monte Carlo is run through cash flow projection with simultaneous adjustments to task durations, cost bases, and escalation rates

1: Excel-based

The effectiveness of the NRA Model relies on the underlying analytics as well as customized, dynamic features

Key Model Characteristics

- Dynamic, risk-adjustable schedule
- Dynamic, risk-adjustable cash flow projection linked to project schedule
- Cost breakdown into cost factors with distinct, risk-adjustable escalation rates
- Task specific run rates to simulate cost of schedule extension
- Cost factor specific spend curves to simulate distribution of cost over years
- Uncertainty ranges built into cost estimates and combined with risk in Monte Carlo simulation

- The cost impact assessment is based on a dynamic nominal cash flow projection by schedule task and across the construction period
  - Baseline cost estimates are adjusted for risk via overnight costs, escalation factors, and schedule extensions
  - Baseline schedule estimates are adjusted for risk via duration extensions for individual schedule tasks
  - Resulting project completion date depends on aggregation of schedule task start dates, durations, and inter-dependencies
  - Costs by schedule task are summed for each year to yield total project costs
- The combined impact of the risk factors is assessed through a Monte Carlo simulation that generates a distribution of commercial operation dates, project costs, and lost margin opportunity
  - The impact of risks on financing costs is modeled through alternative scenarios
- Significance of individual risks can be measured by a covariance analysis and by isolating risks to assess discrete impact

The Project Risk Register documents specific attributes for each risk, including likelihood and impact

Risk Register Overview

Attributes

Attribute	Description
Risk Name	A short title for each risk which allows for ease of identification
Risk Description	A detailed, qualitative description of an event and consequence's
Risk Category	Predefined risk categories to group each risk by primary driver
Likelihood of Occurrence	Probability associated with this risk occurring
Schedule Tasks, Cost Factors, and Escalation Rate Impacted	The activity (or group of activities) associated with the cost or schedule impact
Impacts	Incremental cost or schedule impact relative to baseline across a defined distribution if risk event occurs
Impact Interdependencies	AND, OR, and AND/OR relationship between impacts for a single root cause (i.e. for covariance)

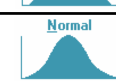
Risk Categories

Regulatory risk	Financial risk
Political risk	Market risk
Project risk	Technology risk

Likelihood of Occurrence

Level	Probability
Uncertainty (e.g., commodity price	100%
Very Likely	95%
Likely	82.5%
Possible	50%
Unlikely	17.5%
Very Unlikely	5%

Impact / Distribution

Distribution	Impact
	Most likely, low, and high values
	Mean and standard deviation
	Mean and standard deviation

The risk register captures broad details associated with each risk (New Nuclear partial register example)

No.		Risk Factor Name	Root Cause	Risk Description	Risk Category	Likelihood of Occurrence	Cost or Schedule Element Impacted	Distribution	Impact Values Low	Impact Values Mode / Mean	Impact Values High / StDev
78	78	Design Change During COLA	Design changes during DCD review process	If FOAKE design leads to design changes during the DCD review process, then rework would result in SER and COL schedule delays	Technology	Unlikely	NI / TI Engineering duration	Triangular	3	6	12
79	79a	Engineering Completion	Inadequate detailed design engineering	If detailed design engineering completion percentage is less than needed for construction, then construction start would be delayed	Project	Possible	NI / TI Engineering duration	Triangular	3	6	12
79	79b						Final design approval & rule-making duration	Triangular	3	6	12
79	79c						ESBWR engineering cost basis ($MM)	Triangular	$10	$20	$30
39	39a	DOE 2010 Program	Congress reduces DOE NP2010 Program funding	If Congress reduces DOE NP2010 Program funding for the development of the design, then GEH engineering cost would increase to offset the reduced funding	Political	Possible	NI / TI Engineering duration	Triangular	3	4.5	6
39	39b						ESBWR engineering cost basis ($MM)	Triangular	$48	$96	$192
75	75	EPC Contract Terms & Conditions	EPC & owner disagreement	If EPC contract terms and conditions can not be agreed in a timely manner, then project schedule would be delayed	Project	Possible	EPC Contractual Agreement duration	Triangular	3	6	12
76	76	EPC Role Modification	EPC role change	If GEH role is modified, extending contract negotiation, then project schedule would be delayed	Project	Very Unlikely	EPC Contractual Agreement duration	Triangular	2	3	6
29	29	DOE Loan Guarantee Aproval Process	DOE loan guarantee approval delay	If DOE loan guarantee approval process is delayed, then the CPCN approval would be delayed and cost of debt would increase	Political	Possible	Obtain approval for guarantee duration	Triangular	0	6	12

The cost baseline can be mapped to a level of the WBS that facilitates meaningful visibility

Cost to Schedule Mapping for WBS

Original Cost Estimates by Category

% represents proportion of baseline cost estimate allocated to corresponding Project Schedule Task

WBS ID	Project Schedule Tasks	Start Date (--------Baseline--------)	Duration (months) (--------Baseline--------)	EPC Engineering & HQ	Reactor Procurement	Turbine Procurement	Common Construction	Reactor Construction	Turbine Construction	Simulator (hardware & software only)	Construction Management	Simulator & Training Building	BOP Construction	ESP/ COL & Planning	Switchyard, Transformers	Permits	Land	Security	Local Inspection	NRC ITAAC	Construction Power	Legal	Cost, real $M (no contingency, no foreign exchange adj)
				$100	$800	$400	$100	$1,000	$500	$25	$200	$16	$1,000	$150	$100	$10	$10	$20	$10	$20	$20	$10	**$4,868**
1.0	Engineering & Contracting																						
1.1	Reactor & Turbine Engineering	1/1/2008	94	90%																			$90
1.2	EPC Contractual Agreement	3/1/2008	9											5%									$7
2.0	Financing																						
2.1	Request federal loan guarantee	6/16/2008	3											2%									$2
2.2	Submit federal loan guarantee	**9/11/2008**	2											1%									$2
2.3	Obtain approval for guarantee	**11/6/2008**	4																				$0
2.4	Secure initial financing	3/14/2008	12											7%									$10
3.0	Licensing																						
3.1	Prepare DCD	12/1/2008	7	10%																			$10
3.2	Processing NRC requests for additional information	1/1/2008	14											8%									$11
3.3	Final design approval & rule-making	**5/30/2008**	25																				$0
3.4	Prepare & submit state licensing	1/7/2008	24											13%									$21
3.5	State license approval	**12/31/2009**	9																				$0
3.6	Prepare environmental impact study	1/14/2008	23											13%									$19
3.7	Obtain environmental permits	1/1/2008	38											21%		100%			100%			50%	$56
3.8	NRC issue SER with open issues	2/1/2008	15																				$0
3.9	Respond to SER issues	**4/20/2009**	11											6%									$9
3.10	Issue final SER	**3/31/2010**	5																				$0
3.11	ASLB hearings	**8/30/2010**	12																				$0
3.12	COL issued	**8/22/2011**	0.0											19%									$28
3.13	Transmission permit application preparation	8/22/2011	12											7%								50%	$15
3.14	Transmission permit approval process	**8/16/2012**	24																				$0
3.15	ITAAC	8/30/2010	42																	100%			$20
4.0	Site Separation & Preparation																						
4.1	Construction planning	3/3/2008	38					5%	5%														$75
4.3	Site preparation engineering	3/2/2009	10																				$6
4.4	Site preparation	**12/29/2009**	28				100%				-8%		26%				100%						$351
5.1	Yard																						
5.1.1	Yard Equipment and Systems Construction	**6/1/2010**	0																				$0
5.1.2	Transmission clearing & construction	**7/5/2012**	6												100%						3%		$101
5.1.3	Pre-safety related concrete balance of plant	6/1/2010	25										20%								14%		$203
5.1.4	Post safety-related concrete balance of plant	**7/5/2012**	48										54%					100%					$564

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The cost baseline links costs and schedule by the allocation of each cost category to one or more schedule tasks

Example

Cost to Schedule Mapping (extract)

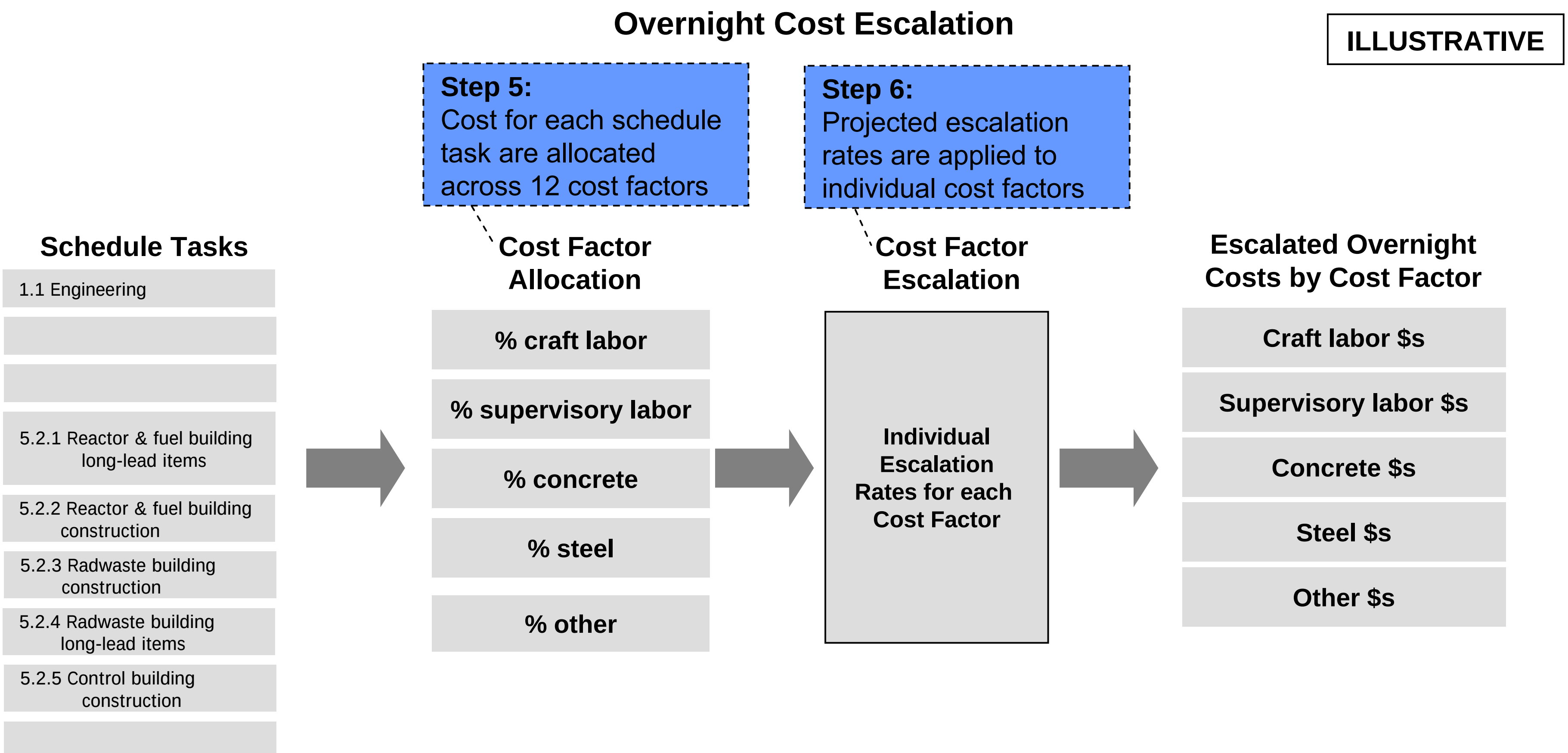
Step 1:
Baseline cost estimates

Step 2:
Percentage of baseline costs allocated to each schedule task

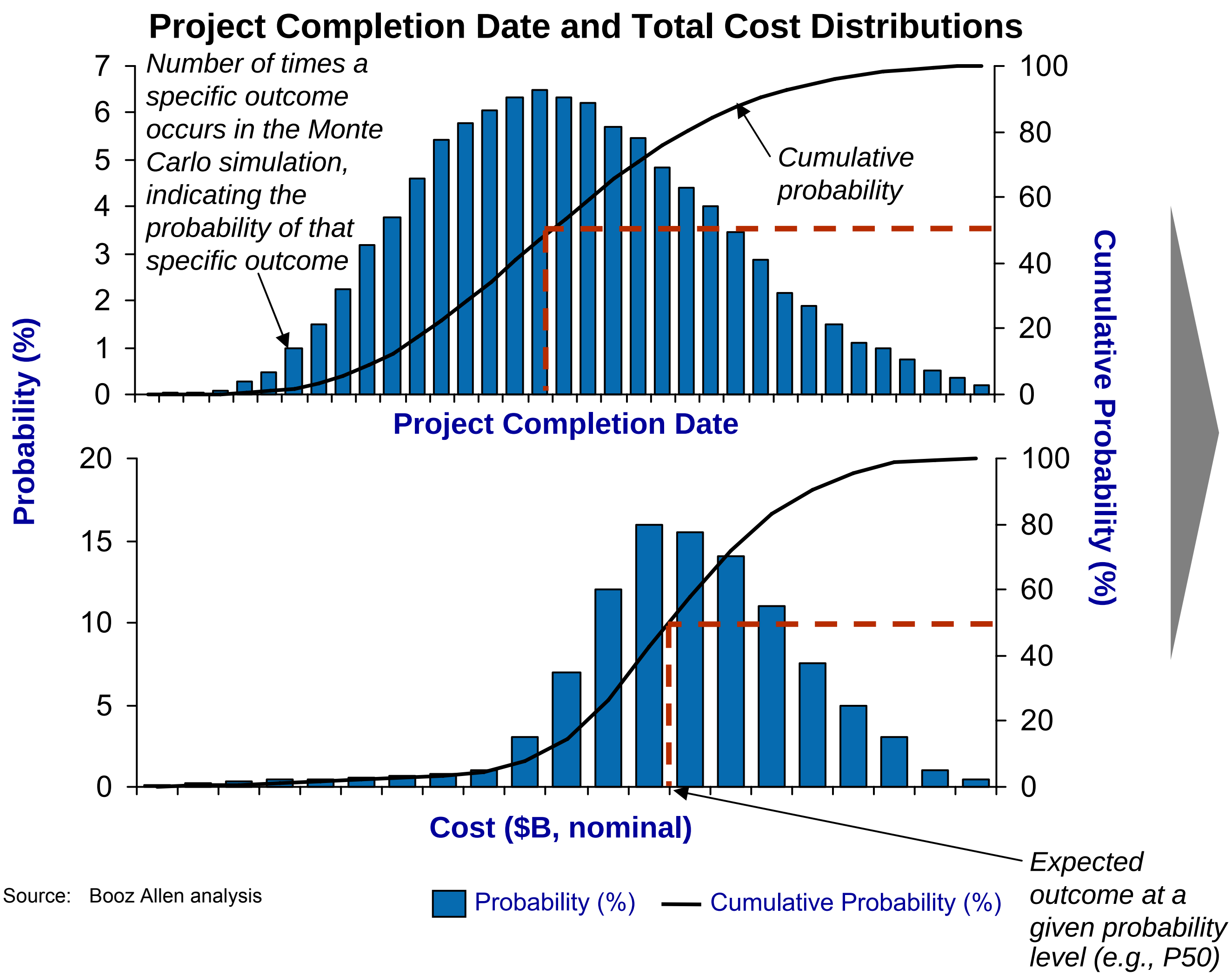
Step 3:
Each schedule task cost is allocated to individual cost factors

Schedule Tasks	Engineering	…	NI Procurement	NI Construction	Construction Management	Construction Power	…	
	$__		$__	$__	$__	$__		
1.1 Engineering	100%							$__M
•								
5.2.1 Long lead items			15%	38%	30%	19%		$__M
5.2.2 Component A construction			32%	24%	19%	12%		$__M
5.2.3 Component B construction			20%					$__M
5.2.4 Component C equipment			2%	38%	30%	19%		$__M
5.2.5 Component C construction			32%					$__M
•					21%	50%		
Totals:	**100%**		**100%**	**100%**	**100%**	**100%**	**100%**	

Each schedule task cost estimate is then associated with cost factors to build a basis for cost and escalation risks



Probability distribution outputs provide a view into the range of outcomes given the identified risk impacts



Source: Booz Allen analysis

- Contributions to cost variance from baseline can be disaggregated into separate probability distributions:
  - Cost basis
  - Escalation rates
  - Schedule extensions
- The distribution for each element can be viewed individually or aggregate in a total project cost perspective

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The risk model generates schedule and cost projections for baseline, pre-mitigation, and post-mitigation assessments

Risk Assessment Model Output

	Model Output Data	Baseline Case	Pre-Mitigation Risk Adjustments	Post-Mitigation Risk Adjustments
Primary Model Output	Project Completion Date	• Based on non-risk-adjusted schedule	• Distribution of project completion dates based on simulation across all schedule risks	• Distribution of project completion dates after mitigation of most critical schedule risks
	Overnight Costs Escalation Costs Schedule Extension Costs *Total Project Costs*	• Overnight costs gathered from vendor quotes and internal planning and adjusted for uncertainty based on percentage engineering completion • Escalation costs represent an adder to overnight costs based on base case escalation assumptions for labor and materials • Schedule extension costs equal to zero because task durations aligned with baseline schedule	• Distribution of overnight, escalation, and schedule extension costs (and total project costs) based on simulation of all cost and schedule risks • For any task where duration exceeds baseline schedule case, this extension is converted into a monthly 'run rate' to project schedule extension cost	• Distribution of total project costs after mitigation of most critical cost and schedule risks
	Project-period Financing Costs	• Cumulative financial carrying costs (debt & equity) through project completion date		

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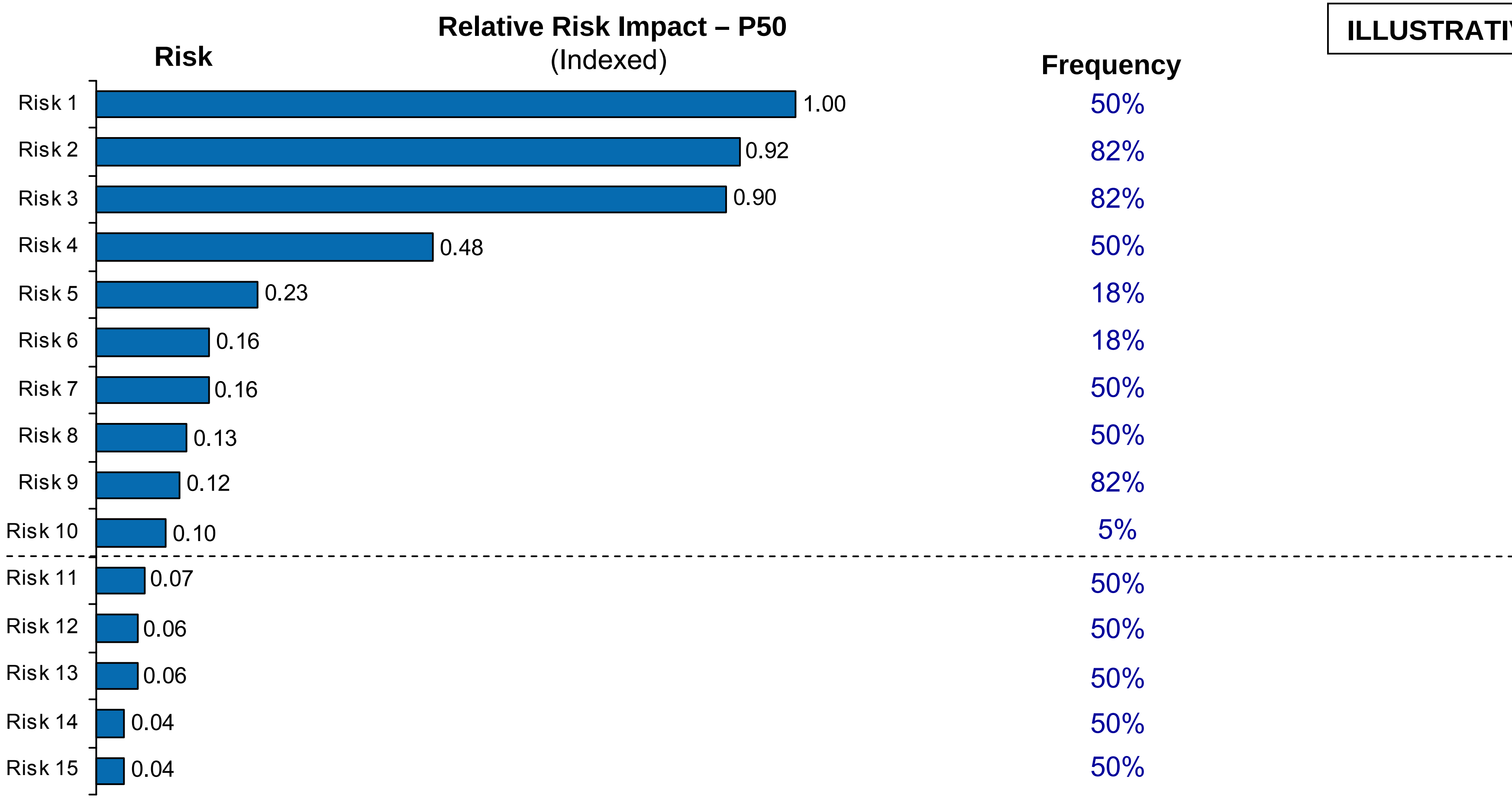
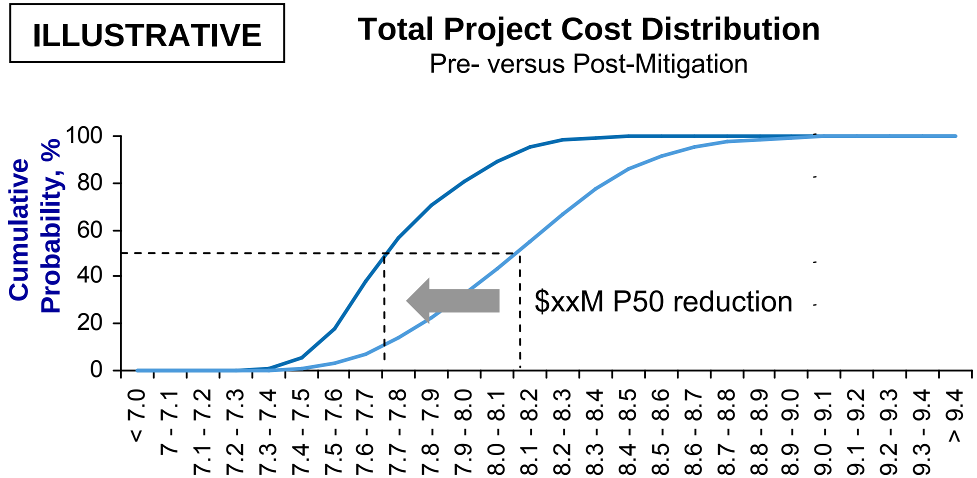
Risk factors can be prioritized based on their relative impact on schedule and cost to aid in mitigation planning

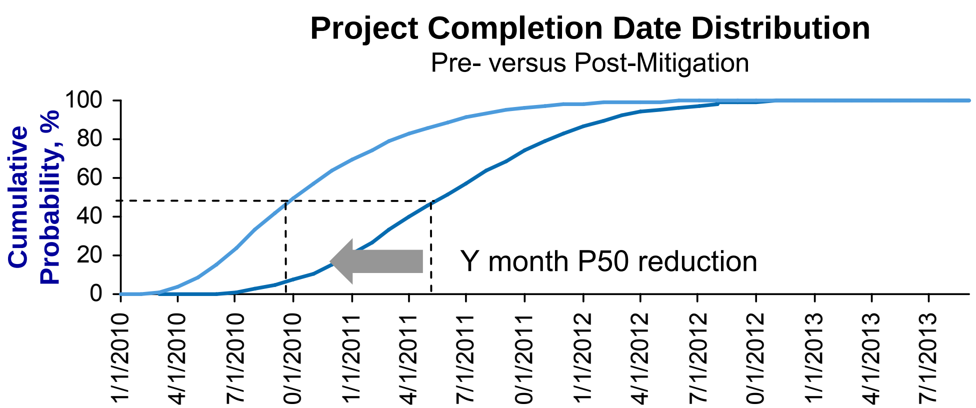
ILLUSTRATIVE



Aggregation of the resultant mitigation actions reveals the potential to reduce overall project schedule and cost risks

ILLUSTRATIVE





Illustrative Mitigation Actions

- Owners rights vs.EPC are clearly defined to include oversight roles and responsibilities
- Performance reporting requirements are specified including minimum standards
- Develop detailed construction plans and sequence activities in a way that minimizes the potential for interference
- Perform detailed review of construction schedules and resource loading plans for potential productivity bottlenecks
- Create a mechanism, e.g., a roundtable, to obtain craft input on key hiring training and retention issues
- Partner with local governments on program design for craft workforce attraction and training
- Establish mandatory hold and witness points in equipment vendor fabrication process

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Lessons learned from mega-projects risk analysis:

- Stability is unlikely. Risks will change as project circumstances evolve. Owners cannot rely only on front-end risk analysis to carry them through the project.
- Recurring risk assessment allows owners to factor into the analysis additional information and insights as they become known. A continuous view of risk allows the owner to react with fore-sight, rather than in desperation.
- Expect the unexpected. Even the most elegant plans can go awry for a multi-year project, particularly one where the early planning work occurs eight to ten years in advance of the actual completion date and includes first-of-a-kind engineering.

Lessons learned from mega-projects risk analysis:

- It is important that project owners get the fundamentals right starting with planning
  - Establishing workable financing structures
  - Meeting regulatory needs
  - Demonstrating capabilities to execute
  - Detailed and reasonable risk apportionment
- Underestimation is common. Since most mega-projects under-perform, it is logical that owners would thoroughly assess their risk in recognition.
  - They need to elevate the intensity of their risk analyses; the premise that "lightning won't strike twice" can be an expensive lesson to learn—again.
  - Yet, many owners believe that their project will be different and immune to the circumstances that befell others.

How can DOE benefit from integrating a rigorous risk analysis methodology into complex project and programs?

- Provides a means of assessing the risk of the applicant-not only based on financial but on their project assessment approaches
- Presents a risk profile of top risks of programs and their impacts on schedule and cost assumptions
- Provides a forum for negotiating contracts that could allow for shifting risks to EPC contractors
- Provides an additional methodology to allow for effective project management and adjust to real time situations
- Provides a common forum for stakeholders to evaluate program success