Dynamic cost risk assessment for controlling the cost of naval vessels

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Cost risk analysis à la Dilbert

Cost-overrun problem: Déjà-vu

"Their judgment was based more on wishful thinking than on sound calculations of probabilities."

Thucydides, 431 B.C.E.

- Thucydides' observation is very insightful and still appropriate today
- Significant problems in cost estimates (2006 RAND study)
  - Systematic bias toward underestimating weapon systems
  - Substantial uncertainty in cost estimates
- Congress has concerns about shipbuilding estimates

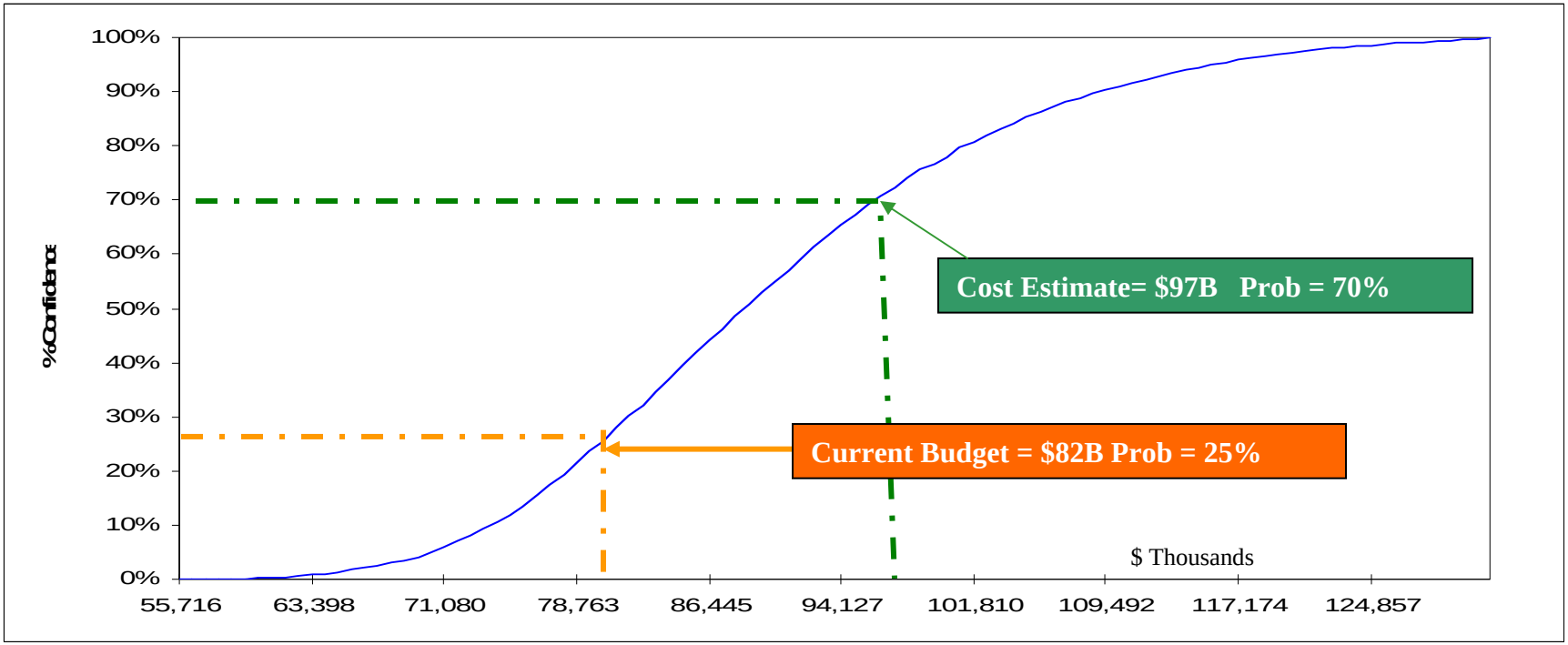
  NavyTimes, March 20, 2008, " Analyst: Lawmakers do not trust Navy numbers"

The use of Probabilistic Cost Analysis (PCA)

- Major shift in R&D and complex projects from deterministic to probabilistic cost analysis
  - Proper framework for handling cost uncertainties
    - Systemic problems
    - Project specific risks
- DoD recognizes that uncertainty or risk is an important aspect of cost analysis
  - NAVSEA 05C implements PCA in the Planning, Programmatic, Budgeting, and Execution System
- Dr. Etter, Former Assistant Secretary of the Navy for Research, Development, and Acquisition

  "Program managers not only need to know a realistic cost estimate for their program, they need to know the percent probability of achieving that target."

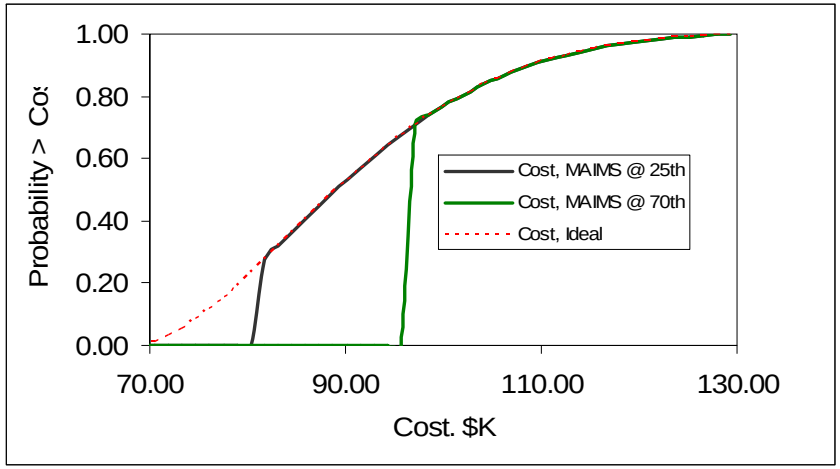
Representative probabilistic cost analysis

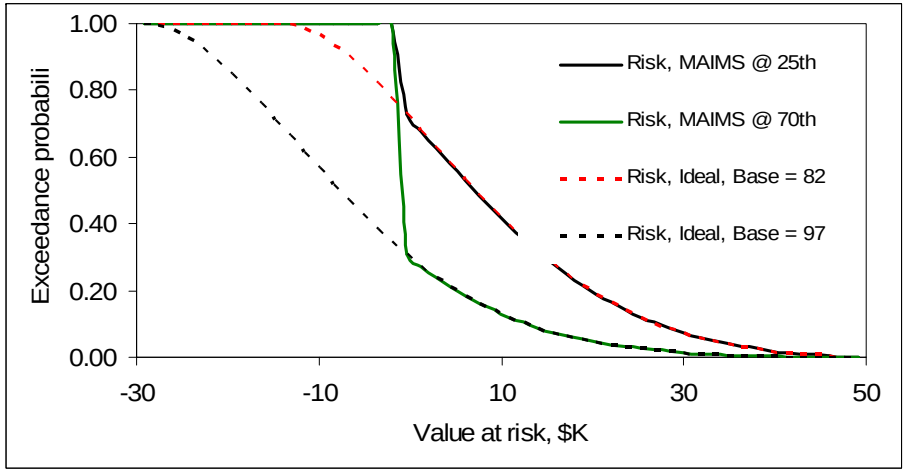


- How much risk are the stakeholders willing to accept?
- Choosing cost point requires understanding consequences.

BUT is today's PCA the silver bullet that slays the cost overrun problem?

Budget allocation impacts project cost and probability of success





Mythical Projects

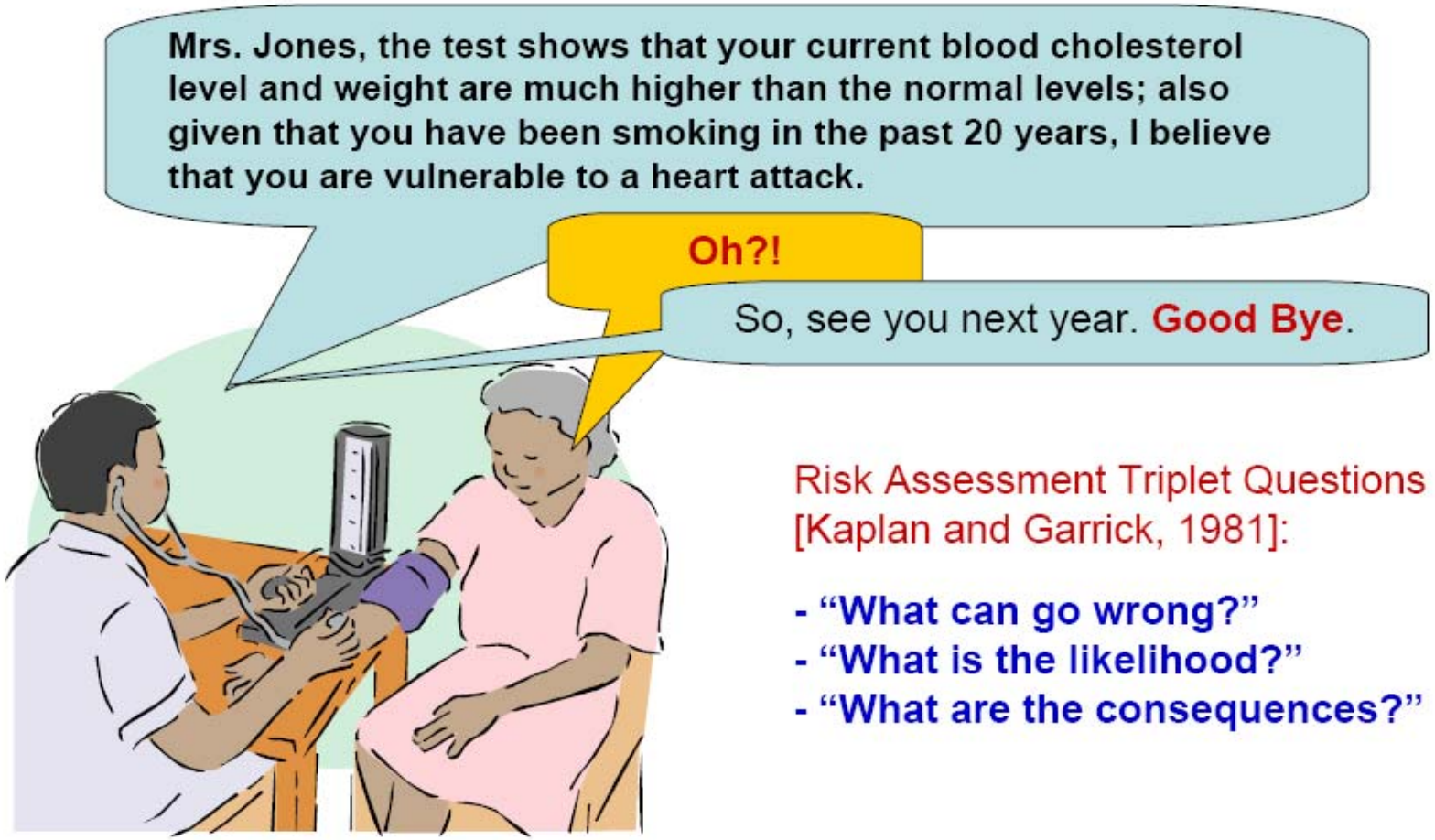
- "100% Rational" project team
- Each project spends only as necessary to satisfy requirements
- Actual cost may be less than budgeted costs

Real Projects

- Human & organizational influences
- MAIMS principle: "Money Allocated Is Money Spent"
- Actual cost increases with higher allocated budget

- *High cost NEED NOT provide high probability of success.*
- Choosing cost point requires understanding consequences.
- Today's typical PCA relies on expected values and underestimates cost.

Probabilistic cost analysis
A physician metaphor

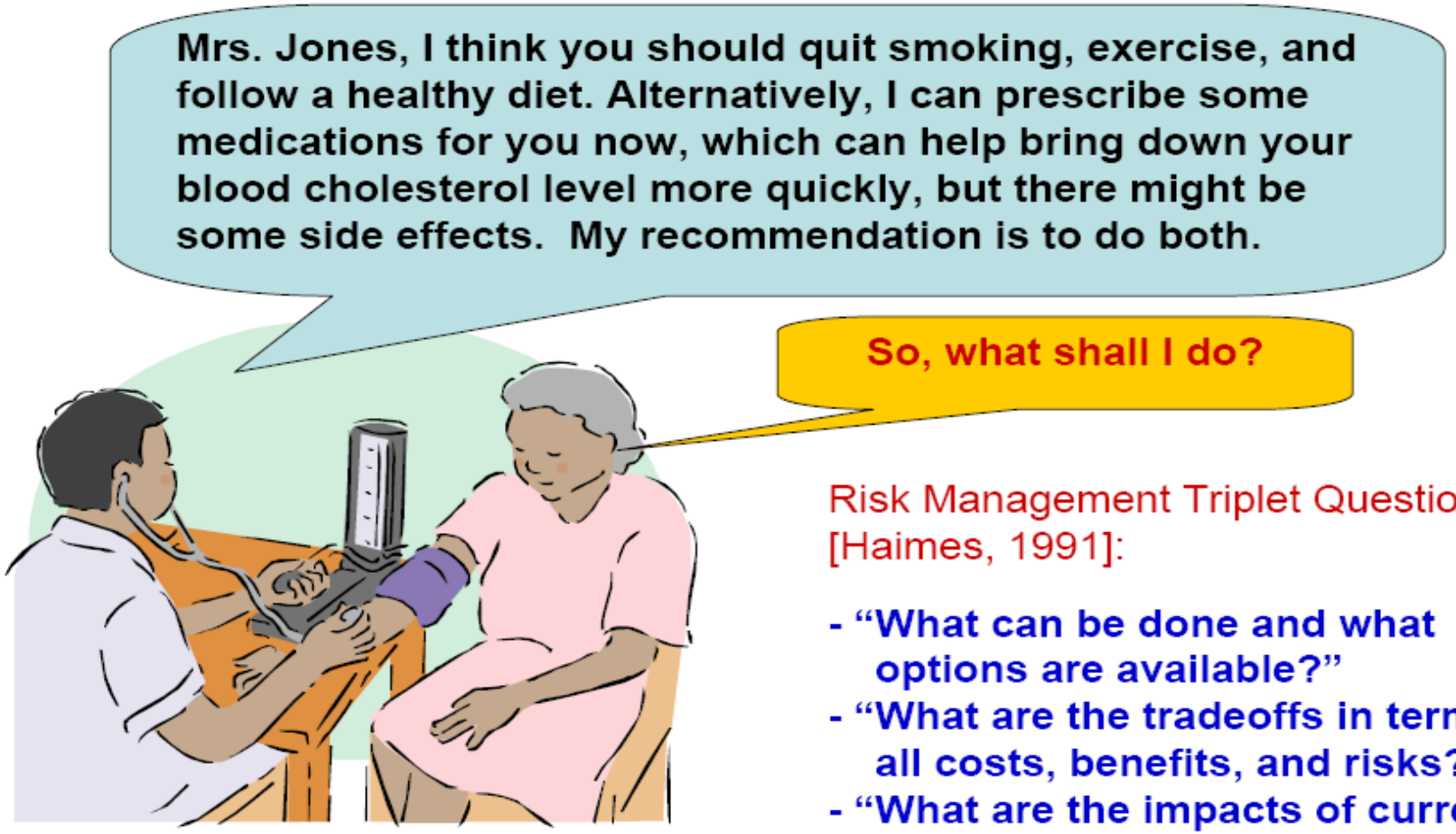


Risk Assessment Triplet Questions [Kaplan and Garrick, 1981]:

- **"What can go wrong?"**
- **"What is the likelihood?"**
- **"What are the consequences?"**

Adapted from Yacov Y. Haimes, NPS 2007

Dynamic cost risk management
A physician metaphor



Risk Management Triplet Questions [Haimes, 1991]:

- "What can be done and what options are available?"
- "What are the tradeoffs in terms of all costs, benefits, and risks?"
- "What are the impacts of current decisions on future options?"

Adapted from Yacov Y. Haimes, NPS 2007

Sources of cost uncertainty

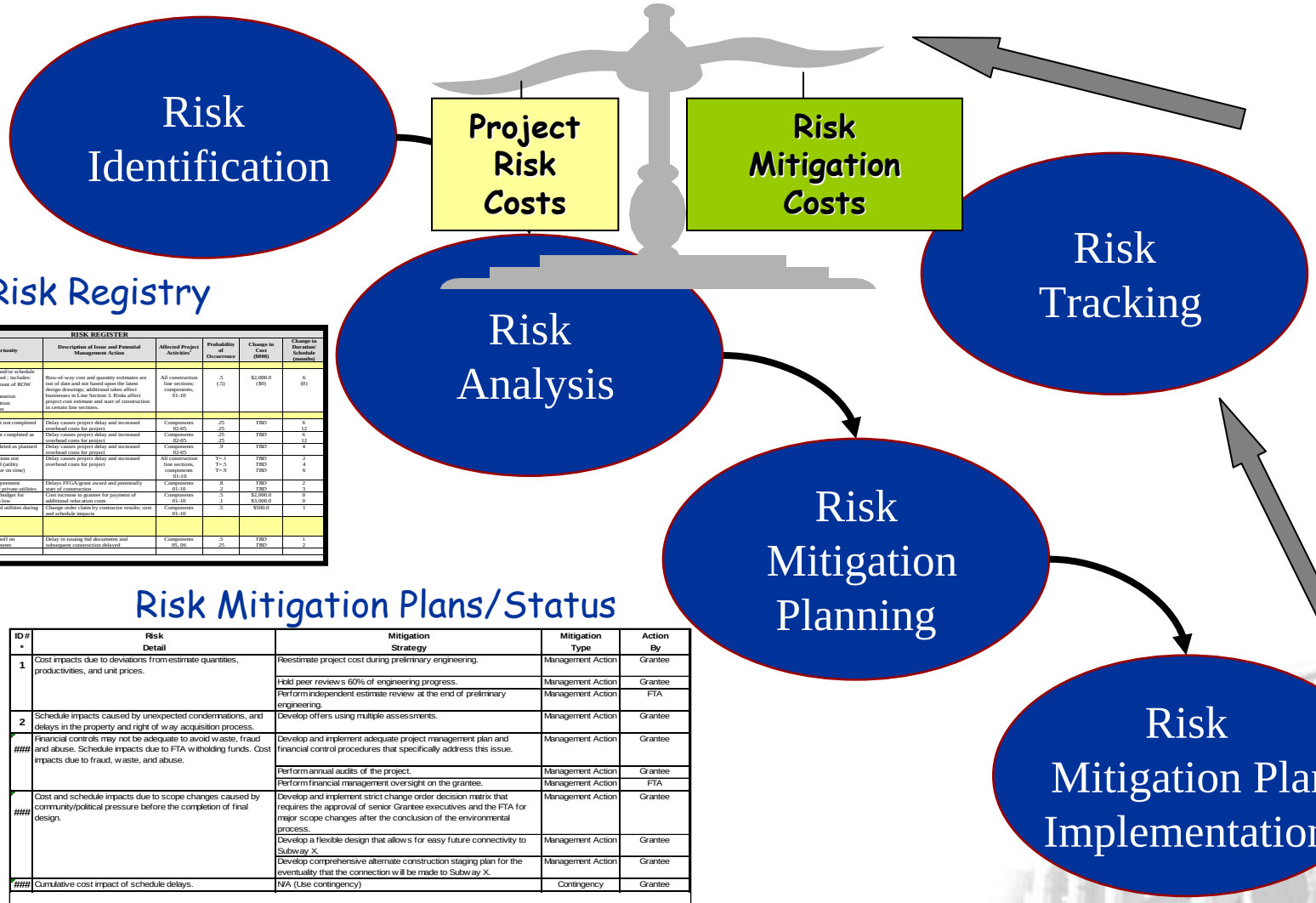
Macroscopic analysis

- Economic, Materials & Labor, Learning rates
- Effectively modeled using classical PDFs
  - Triangular, Beta, Lognormal, Weibull distributions, …
- ☹ But these only constitute a fraction of today's typical project risk drivers

Microscopic analysis

- Project-specific, high consequence risks
  - Technology, Design, Change orders,…
- Need to be analyzed within the framework of a complete risk management effort
- Modeling and analysis tools
  - Decision trees, influence diagrams
  - Monte-Carlo simulation

Integrate PCA into the DoD risk management process



Risk Registry

RISK REGISTER

Project Component	Risk ID	Risk/Opportunity	Description of Issue and Potential Management Action	Affected Project Activities[1]	Probability of Occurrence	Change in Cost ($000)	Change in Duration/ Schedule (months)
1. Right-of-Way							
	R1	Right-of-Way costs and/or schedule greater than anticipated ; includes: • uncertainty in amount of ROW • unit prices • excessive condemnation • relocation, demolition • business mitigation	Row-of-way cost and quantity estimates are out of date and not based upon the latest design drawings; additional takes affect businesses in Line Section 3. Risks affect project cost estimate and start of construction in certain line sections.	All construction line sections; components, 01-10	.5 (.5)	$2,000.0 ($0)	6 (0)
2. Utilities							
	U1	City waterline project not completed as planned	Delay causes project delay and increased overhead costs for project	Components 02-05	.25 .25	TBD	6 12
	U2	City sewer project not completed as planned	Delay causes project delay and increased overhead costs for project	Components 02-05	.25 .25	TBD	6 12
	U3	City vaults not completed as planned	Delay causes project delay and increased overhead costs for project	Components 02-05	.3	TBD	4
	U4	Private utility relocations not completed as planned (utility company fails to move on time)	Delay causes project delay and increased overhead costs for project	All construction line sections, components 01-10	T= .1 T=.5 T=.9	TBD TBD TBD	2 4 6
	U5	Delay in obtaining agreement between grantee and private utilities	Delays FFGA/grant award and potentially start of construction	Components 01-10	.8 .2	TBD TBD	2 2
	U6	Project's adjustment budget for private utilities is too low	Cost increase to grantee for payment of additional relocation costs	Components 01-10	.5 .1	$2,000.0 $3,000.0	0 0
	U7	Encounter unexpected utilities during construction	Change order claim by contractor results; cost and schedule impacts	Components 01-10	.5	$500.0	1
3. Environmental, Permitting, and Agreements							
	E1	Delay in gaining signoff on programmatic agreements	Delay in issuing bid documents and subsequent construction delayed	Components 05, 06	.5 .25	TBD TBD	1 2
ETC.							

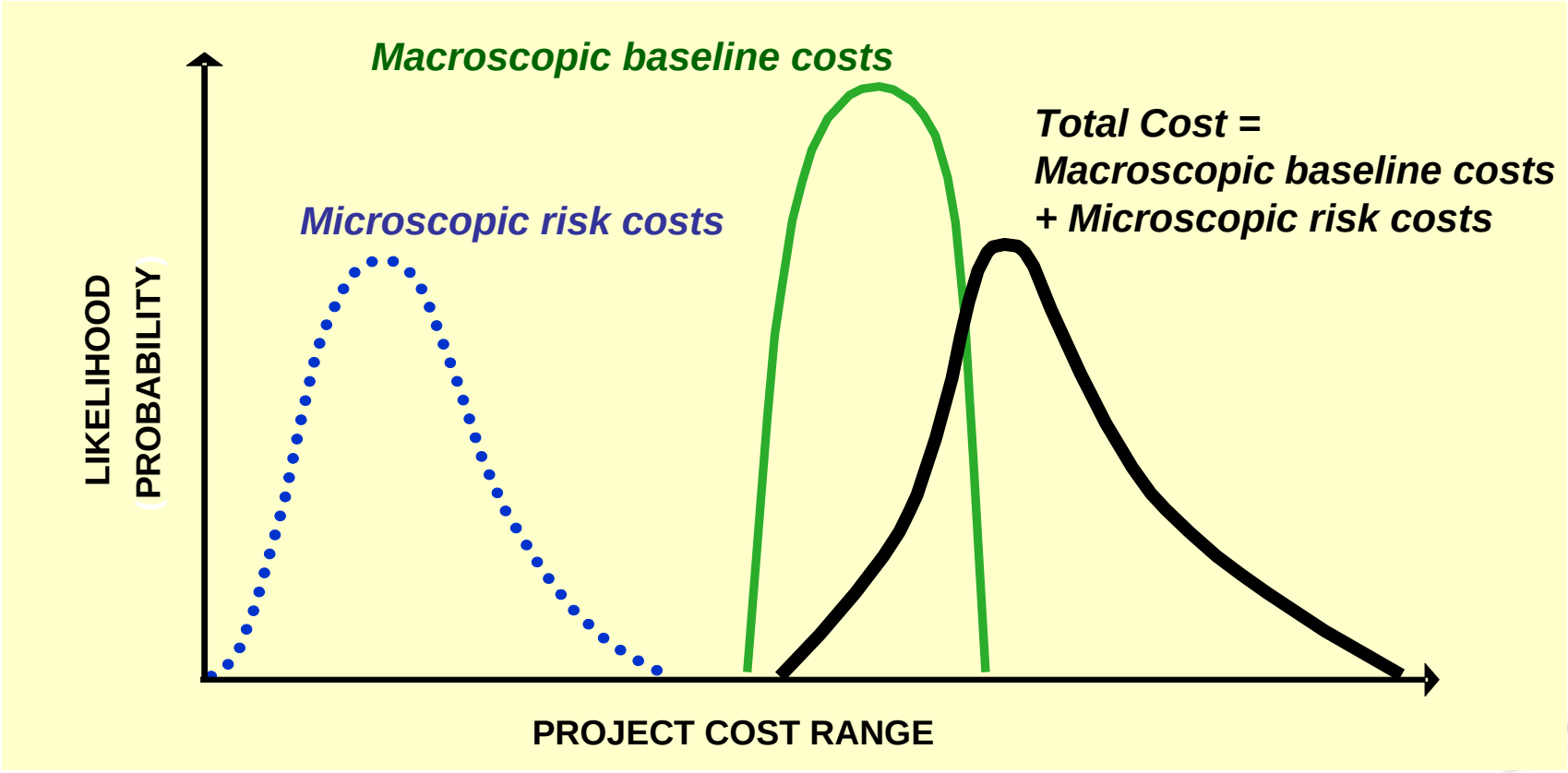
Risk Mitigation Plans/Status

ID# *	Risk Detail	Mitigation Strategy	Mitigation Type	Action By
1	Cost impacts due to deviations from estimate quantities, productivities, and unit prices.	Reestimate project cost during preliminary engineering.	Management Action	Grantee
		Hold peer reviews 60% of engineering progress.	Management Action	Grantee
		Perform independent estimate review at the end of preliminary engineering.	Management Action	FTA
2	Schedule impacts caused by unexpected condemnations, and delays in the property and right of way acquisition process.	Develop offers using multiple assessments.	Management Action	Grantee
###	Financial controls may not be adequate to avoid waste, fraud and abuse. Schedule impacts due to FTA witholding funds. Cost impacts due to fraud, waste, and abuse.	Develop and implement adequate project management plan and financial control procedures that specifically address this issue.	Management Action	Grantee
		Perform annual audits of the project.	Management Action	Grantee
		Perform financial management oversight on the grantee.	Management Action	FTA
###	Cost and schedule impacts due to scope changes caused by community/political pressure before the completion of final design.	Develop and implement strict change order decision matrix that requires the approval of senior Grantee executives and the FTA for major scope changes after the conclusion of the environmental process.	Management Action	Grantee
		Develop a flexible design that allows for easy future connectivity to Subway X.	Management Action	Grantee
		Develop comprehensive alternate construction staging plan for the eventuality that the connection will be made to Subway X.	Management Action	Grantee
###	Cumulative cost impact of schedule delays.	N/A (Use contingency)	Contingency	Grantee

Extended PCA
Dynamic cost risk management

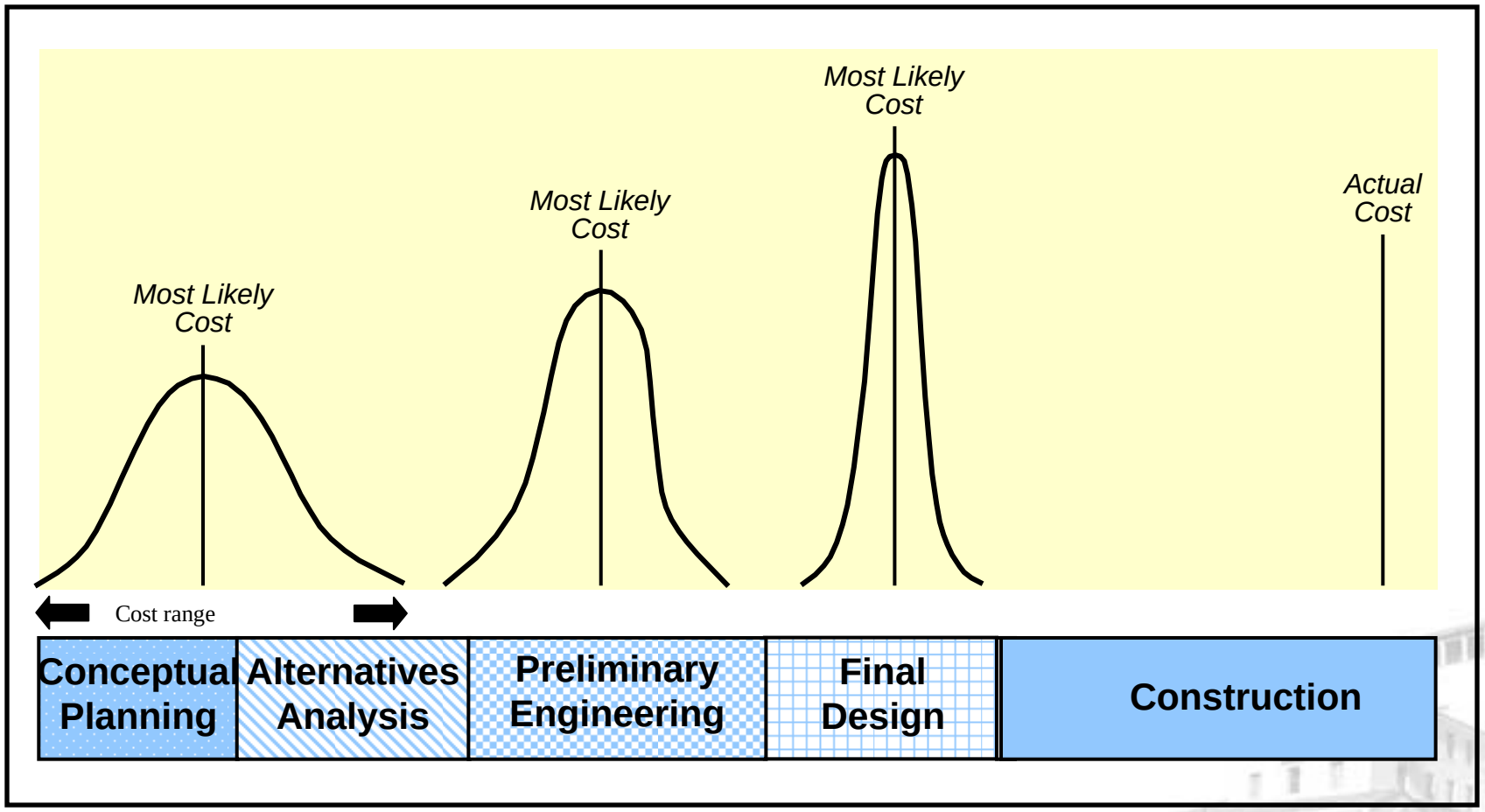
- Identify project-specific risks
- Screen for further analysis and mitigation
- Develop risk response actions
- Model risk and actions using decision tree
- Model cost uncertainty with continuous and discrete distributions
- Use simulation to explore value of risk response actions

Total Project Cost = Baseline Cost + Risk Costs

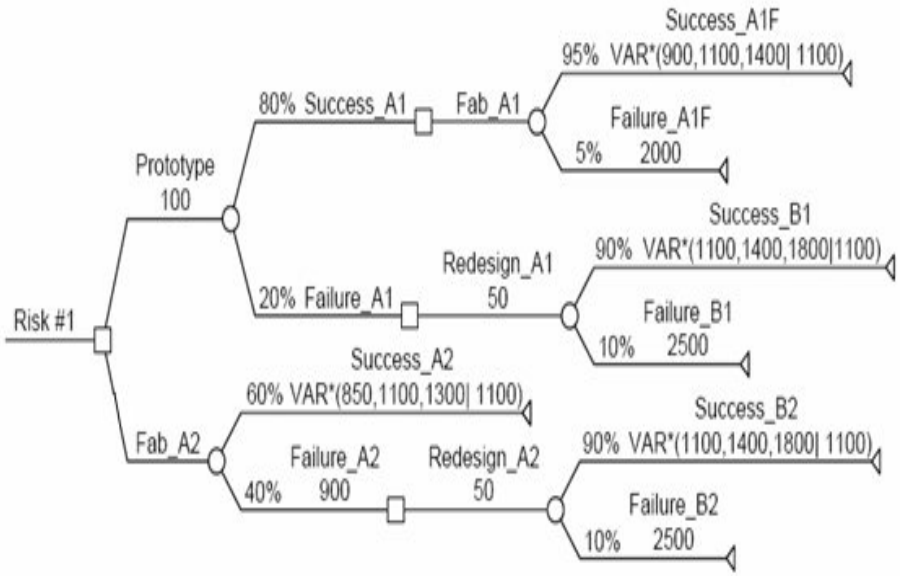


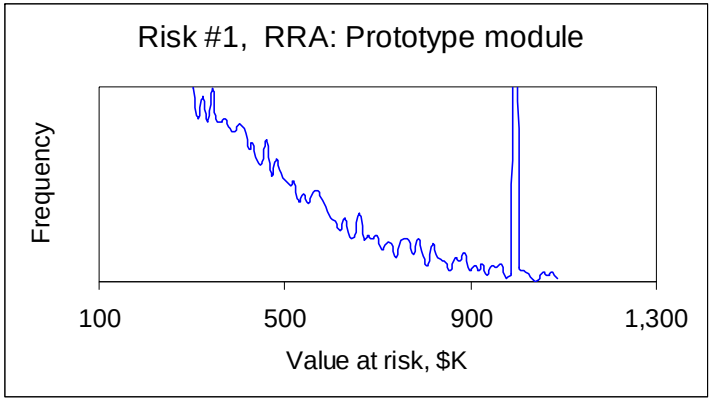
☺ The microscopic view is a powerful risk analysis method
☹ However, it is too cumbersome to individually analyze every risk
☞ It complements and needs to be integrated within the PCA

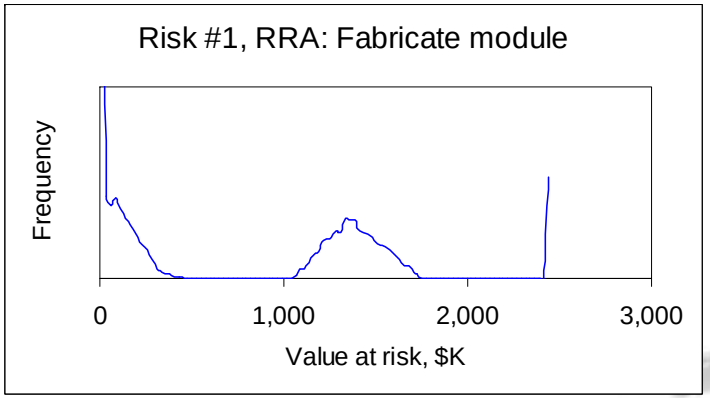
Project cost and uncertainty over time
A very dynamic picture

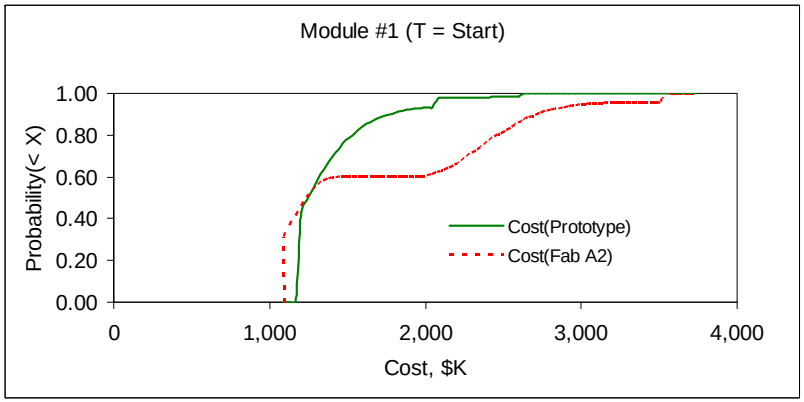


Example #1 – Single risk, Risk #1









- Risk #1 is associated with the fabrication of a complex module
- Two RRAs
  - Directly fabricate module
  - Build prototype first

Enhanced Decision Tree Analysis (DTA)

Standard DTA

- Information lost in folding back
- Decisions based on expected value
- Representation quickly becomes too bushy

Enhanced DTA

- Spectrum of outcomes explicit
- Decisions based on risk profiles and DM's attitude toward risk
- Compact representation
- Readily implemented using commercially available SW

➢ Enhanced DTA provides more complete and meaningful information than standard DTA for the same data.

Multiple risks

- Consider a project/program with m base cost elements $\{BC_j\}$ and n credible, high-consequence risks and/or opportunities $\{R_i\}$
  - Each base cost element may be modeled as a point estimate or continuous PDF
  - Each risk is characterized by a probability of occurrence pi a spectrum of possible outcomes with a PDF $L_i(x)$
- Think of project/program of risks is a risk/opportunity portfolio with a generalized discrete PDF

$$R_S(x) \equiv \left\{ \langle p_1, L_1(x) \rangle, \langle p_2, L_2(x) \rangle, \ldots, \langle p_n, L_n(x) \rangle, \left\langle 1 - \sum_{i=1}^{n} p_i, 0 \right\rangle \right\}$$

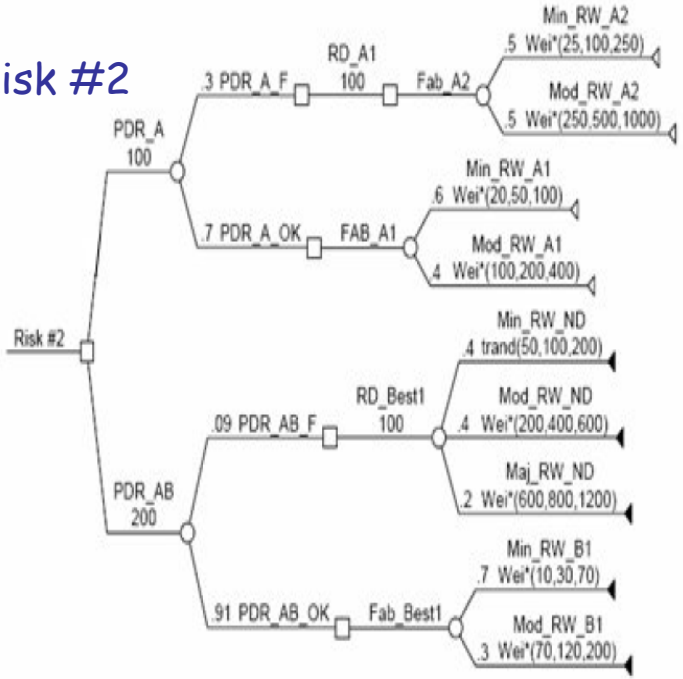
- The total cost is then the probabilistic sum of the m base cost elements and n risk-driver costs

$$TC(x) = \sum_{i=1}^{m} BC_i(x) \oplus \sum_{i=1}^{n} p_i L_i(x)$$

Example # 2 – Project with 3 risks

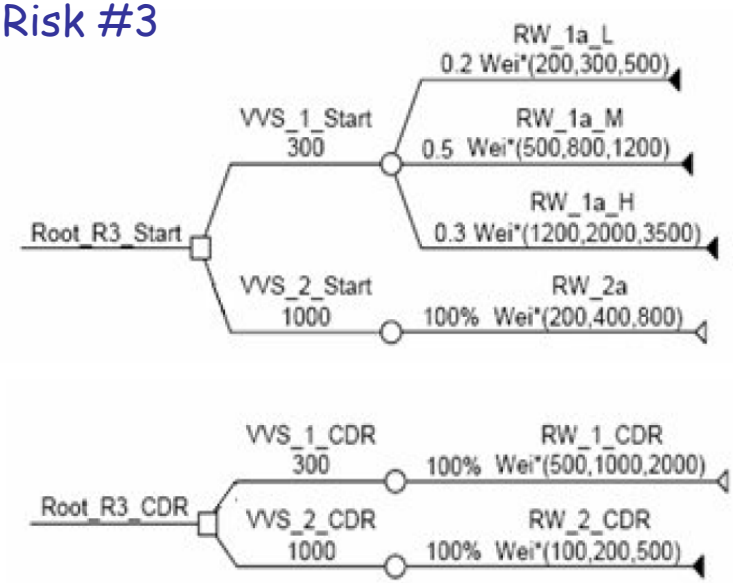
Risk #1 – slide 14

Risk #2



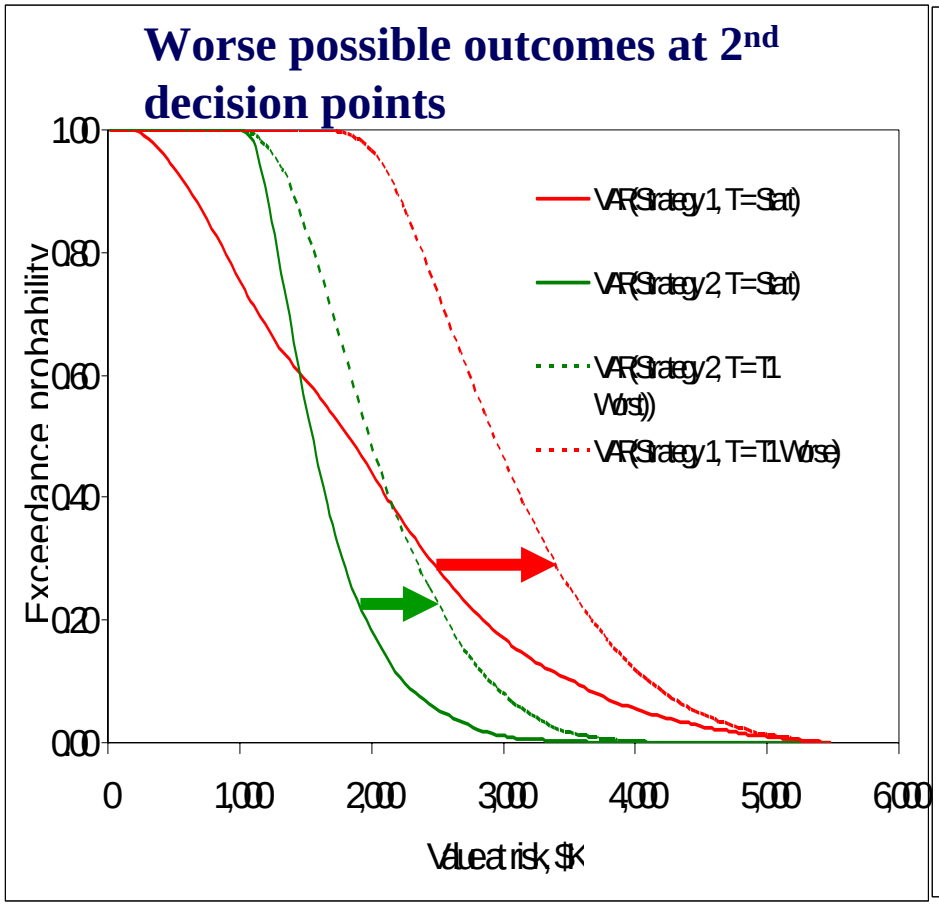
Risk #2: high-risk subcontract
- Single contractor
- Two contractors, downselect at PDR

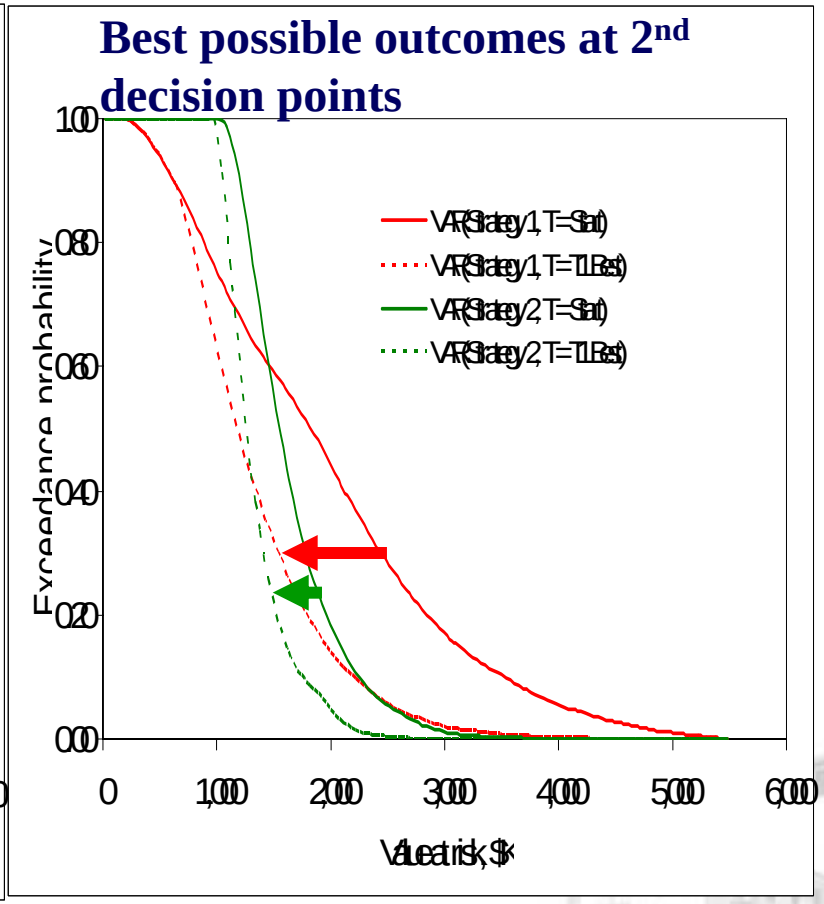
Risk #3



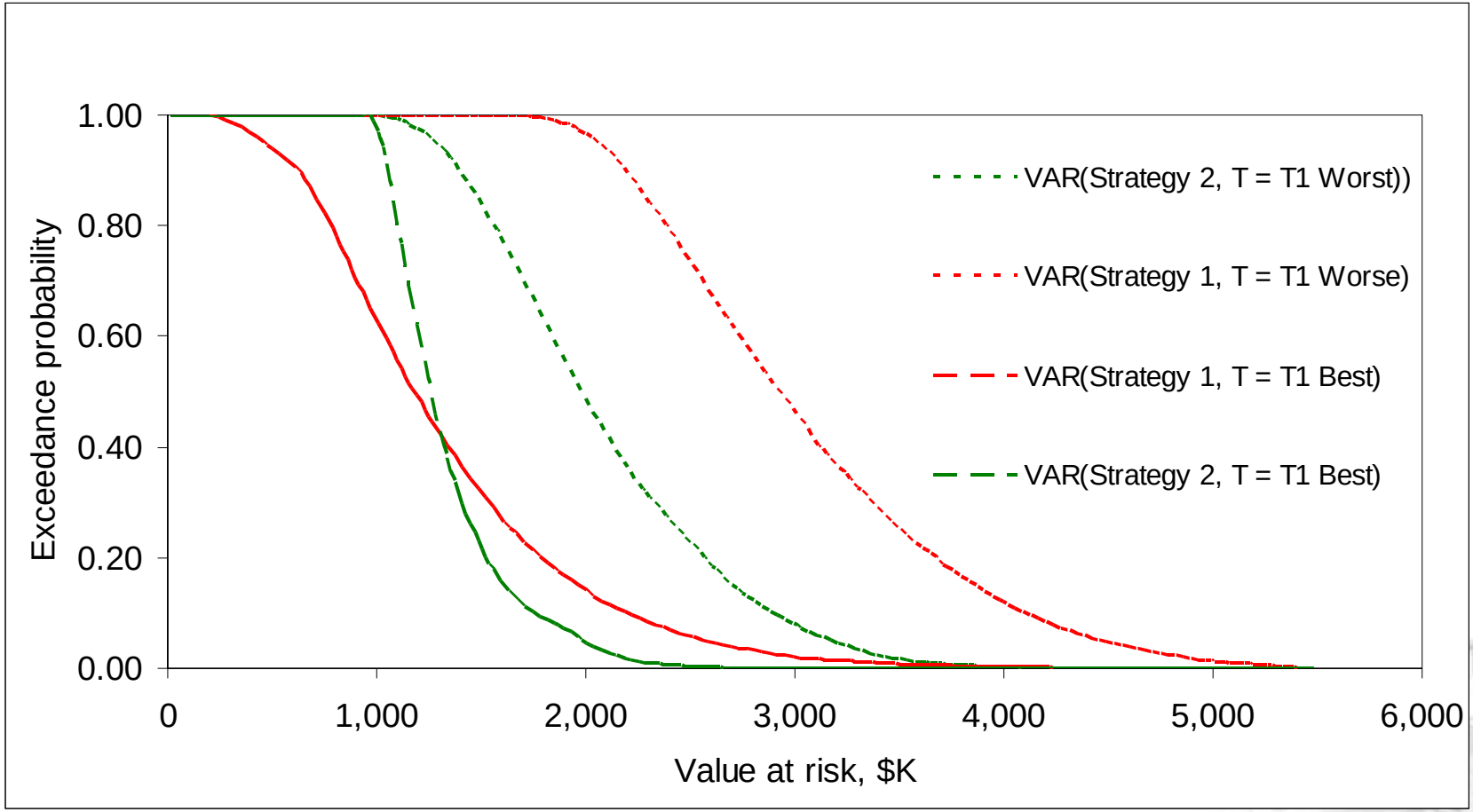
Risk #3: contractor considers two V&V strategies for risk reduction
- Standard V&V
- Extensive modeling and simulation

Example # 2-Dynamic risk curves

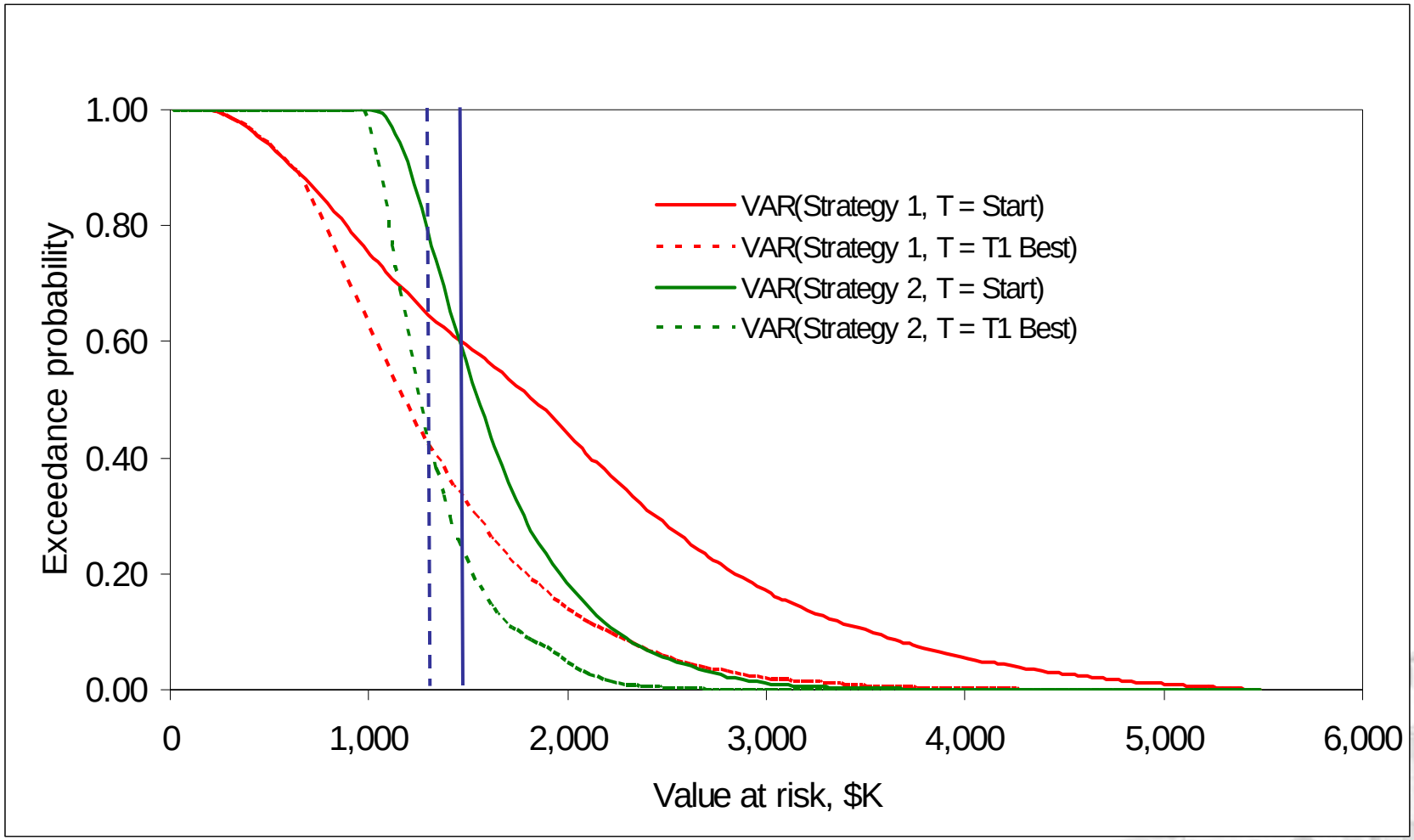




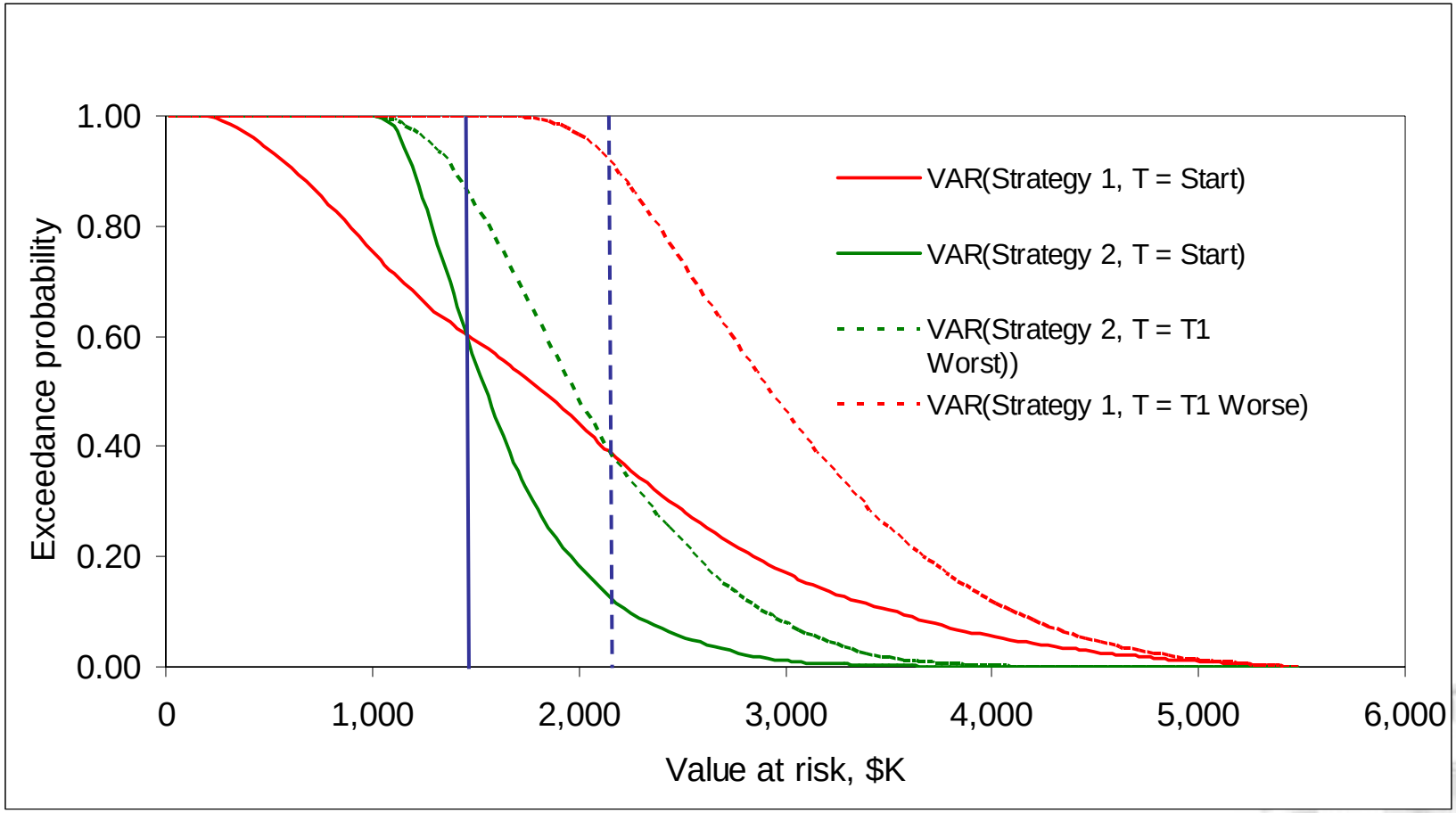
Example # 2 - Range of Risk



Example #2 - Comparing Strategies
(Best Scenario)



Example #2 - Comparing Strategies
(Worst Scenario)



Conclusions

- Project-specific cost risks can be modeled using decision trees and simulation
  - Micro level essential for risk management
- Dynamic risk curve analysis can be used to select and track performance of risk response actions over time
  - Enable cost-risk tradeoffs
- Dynamic risk analysis and management are key to improve project/program technical performance, schedule, and cost

Further Research

- Incorporate multiple risks into dynamic risk analysis and management
  - Solve for optimal risk mitigation strategy
- Expand results to budget implications of cost estimates
- Integrate with schedule and technical performance