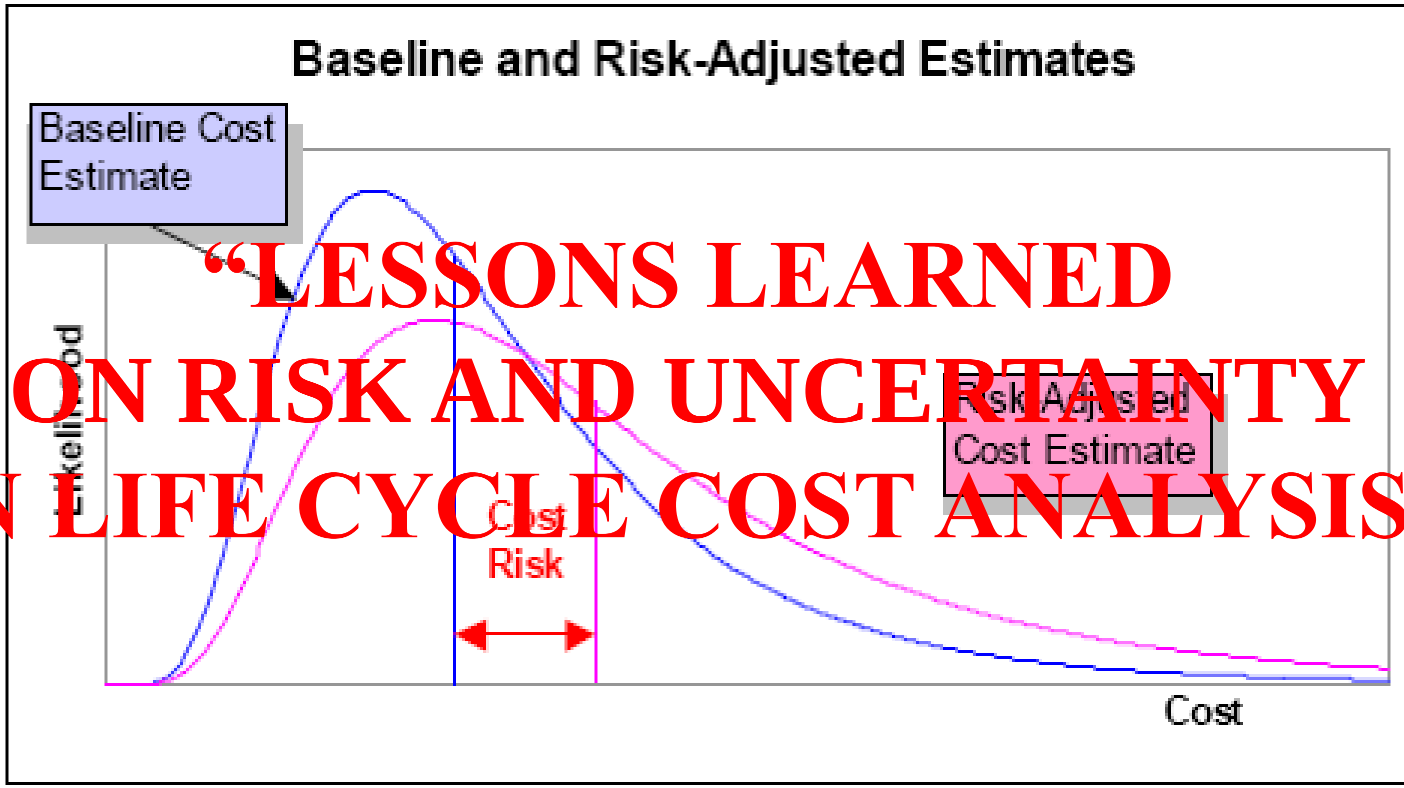
SCAF WORSHOP 2013



“LESSONS LEARNED ON RISK AND UNCERTAINTY IN LIFE CYCLE COST ANALYSIS”

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LCC UNCERTAINTY AND RISK

According to NATO publication ALCCP-1 (NATO Guidance on Life Cycle Costs), Life Cycle Cost estimates of defence programmes are inherently uncertain and risky:

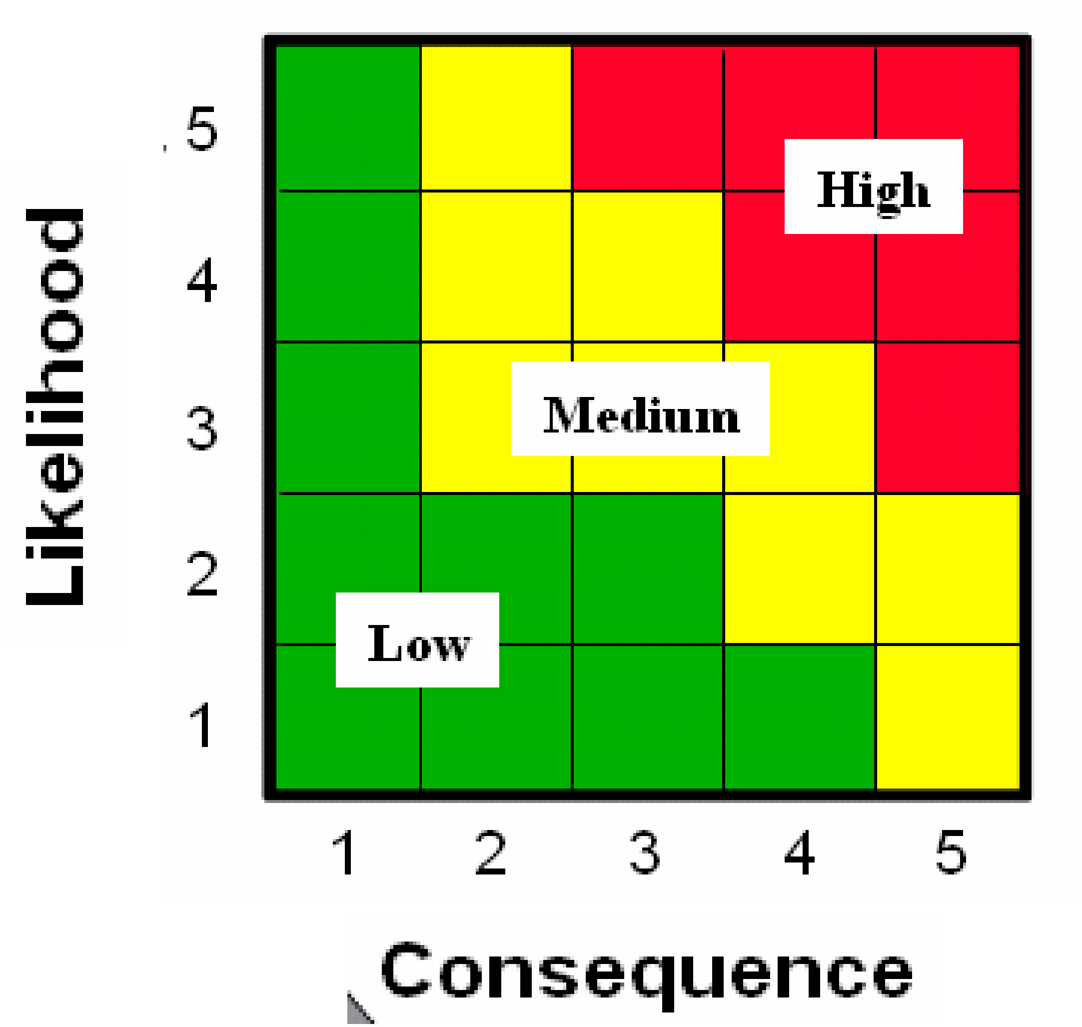
- **Uncertainty** is the indefiniteness or variance of an event.
- **Risk** is exposure to loss.

Risk has two components:

(1) the probability of failing to achieve a particular outcome

(2) the consequences/impacts of failing to achieve that outcome.

RISK MATRIX (1)



RISK MATRIX (2)

Likelihood

What is the likelihood the risk will happen?		
Level		Planned Approach and Processes...
1	Not Likely:	...Will effectively avoid or mitigate this risk based on standard practices
2	Low Likelihood:	...Have usually mitigated this type of risk with minimal oversight in similar cases
3	Likely:	...May mitigate this risk, but workarounds will be required
4	Highly Likely:	...Cannot mitigate this risk, but a different approach might
5	Near Certainty:	...Cannot mitigate this type of risk; no known processes or workarounds are available

RISK MATRIX (3)

Consequence

Given the risk is realized, what would be the magnitude of the impact?			
Level	Technical	Schedule	Cost
1	Minimal or no impact	Minimal or no impact	Minimal or no impact
2	Minor perf shortfall, same approach retained	Additional activities required; able to meet key dates	Budget increase or unit production cost increase <1%
3	Mod perf shortfall, but workarounds available	Minor schedule slip; will miss need date	Budget increase or unit production cost increase <5%
4	Unacceptable, but workarounds available	Program critical path affected	Budget increase or unit production cost increase <10%
5	Unacceptable; no alternatives exist	Cannot achieve key program milestone	Budget increase or production cost increase >10%

COMPONENTS OF COST RISK

Cost Estimating Risk: Risk arising from cost estimating errors and the statistical uncertainty in the estimate.

Schedule/Technical Risk: Risk associated with infeasible tight schedule and the difficulty of conquering the problem posed in the specification phase of the ‘System-of-Interest’ (SOI)

Requirements Risk/Threat Risk: Risk of changing the proposed requirements of the SOI and the risk associated with the change of the threat for which the SOI was designed in the first place.

Troubled programmes normally have a Red status on a Red-Yellow-Green scale of programme health.

COST RISK ASSESSMENT

Defined as the process of identifying and analyzing critical programme risks within a defined set of cost, schedule, and technical objectives and constraints, distinguishing between uncertainty and risk.

The purpose of cost risk assessment is to capture uncertainty in cost methodology, technical parameters, schedule, and programmatic factors.

Baseline estimate is deemed to be the key starting point in generating a cost risk adjusted estimate

COST RISK CLASSIFICATION

COST	RISK		
	High	Medium	Low
LCC < $250M	Category 2	Category 3	
$250M ≤ LCC ≤ $1B	Category 2		
LCC > $1B *	Category 1		

(NASA Cost Estimating Handbook)

DATA COLLECTION AND ANALYSIS

The most important part of the process of estimating risk and uncertainty is data collection and analysis. All variables in the cost estimating model potentially affected by risk and uncertainty first need to be identified.

Probability distributions need to be estimated or selected for each variable.

It is also important in the data analysis to identify discrete risk events, or unfavourable outcomes that might occur in developing, manufacturing, and operating defence systems.

UNCERTAINTY IN BASELINE COST ESTIMATE

A baseline cost estimate is generated using Monte Carlo simulation followed by a risk-adjusted cost estimate.

The baseline estimate captures uncertainty in the relationship between dependent and independent variables in each CER. This uncertainty results from:

Limited data. In explaining changes in the cost of any CBS element, perhaps only two or three factors are included in the analysis. The CER, then, becomes an oversimplification of the complexities of reality, resulting in errors.

Human unpredictability. Randomness in human responses can be adequately characterised only by the inclusion of uncertainty in the analysis.

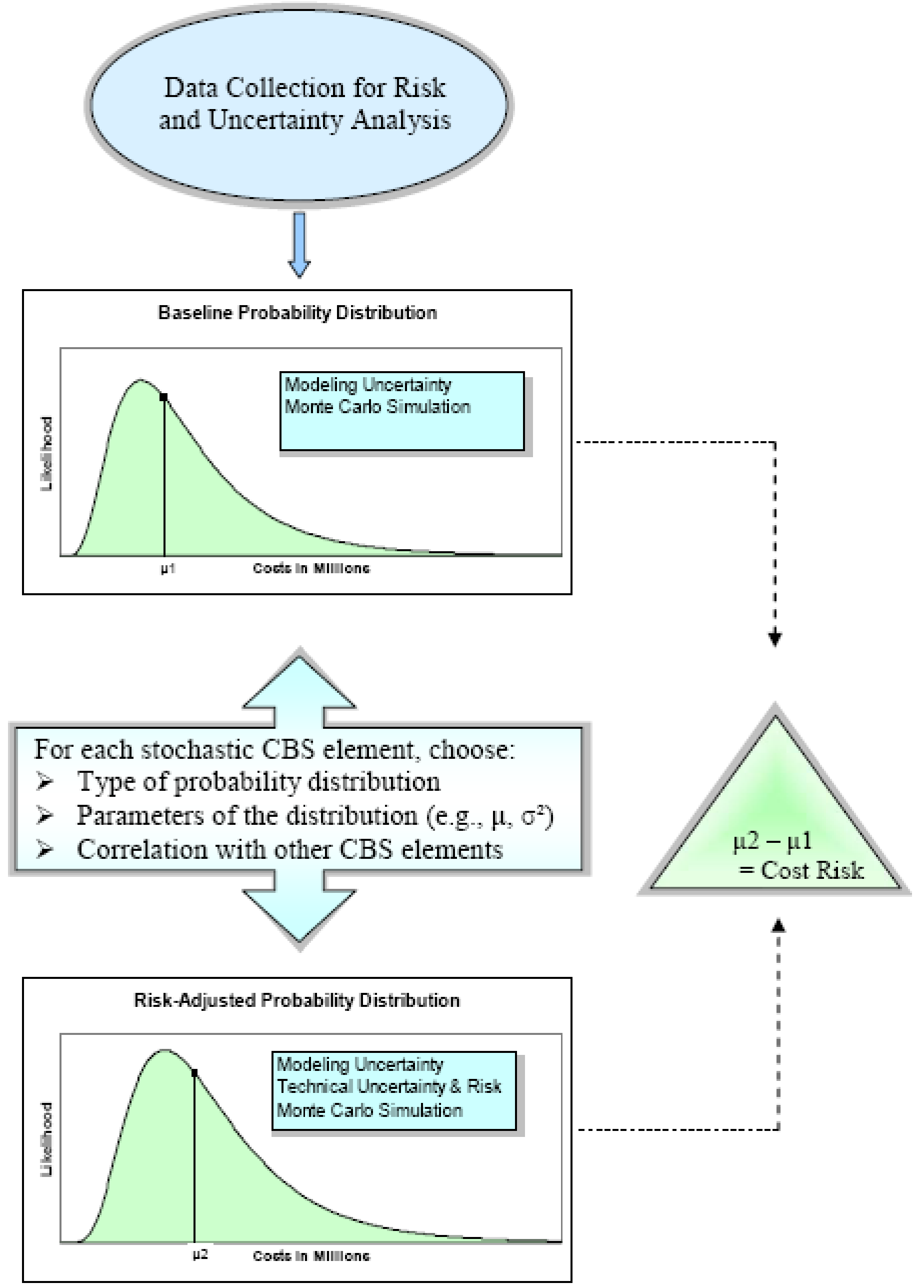
Errors of observation or measurement. Cost and technical data are almost always difficult to obtain and are often of less than perfect accuracy.

BASELINE COST ESTIMATE AND RISK-ADJUSTED COST ESTIMATE

In generating the baseline cost estimate, first the values of the independent variables (X) in each of the cost model's CERs are considered fixed values.

In generating a risk-adjusted cost estimate, not only is basic CER uncertainty captured, as above, but technical risk and uncertainty as well. In this case, the input variables (X) in each of the model's CERs are to be regarded as stochastic.

Monte Carlo simulations allow the analyst to understand the combined effects of multiple risks. The traditional output of a Monte Carlo model is a probabilistic cost distribution (commonly referred to as an S-Curve).


Data Collection for Risk and Uncertainty Analysis
Baseline Probability Distribution
Modeling Uncertainty
Monte Carlo Simulation
Likelihood
μ1
Costs in Millions
For each stochastic CBS element, choose:
Type of probability distribution
Parameters of the distribution (e.g., μ, σ²)
Correlation with other CBS elements
μ2 – μ1
= Cost Risk
Risk-Adjusted Probability Distribution
Modeling Uncertainty
Technical Uncertainty & Risk
Monte Carlo Simulation
Likelihood
μ2
Costs in Millions

RISK ANALYSIS MODELS: HISTORICAL DATA AND EXPERT JUDGEMENT

Risk analysts have traditionally used historical data as an information source in probability assessments, but sometimes the required data is quite difficult to obtain.

In risk analysis where there is little or no relevant historical data, expert judgment is frequently applied. Expert judgment is typically appropriate when:

- Data is sparse or difficult to obtain.
- Data is too costly to obtain.
- Data is open to different interpretations, and the results are uncertain.
- There is a need to perform an initial screening of the problems.

EXPERT BASED RISK MODELS

1. Identify risks through the interview of SMEs.
2. Add the results of these interviews to the estimate.
3. Take the risk adjusted estimate and burden it appropriately.

In general, Monte Carlo models are the method by which multiple effects are combined to develop a top level risk adjusted estimate.

BASIC QUESTIONS OF RISK ANALYSIS

A risk analysis, therefore, fundamentally consists of answering the following questions:

- What can happen?
- How likely is it that it will happen?
- If it does happen, what are the consequences?

OBTAINING THE COST PROBABILITY DISTRIBUTION

The uncertain or random nature of each of the factors, ratios, and CERs in a cost-estimating model can be expressed as a probability distribution with a certain mean and variance.

Combining the probability distributions of each of these stochastic variables in a large cost model for a major system acquisition programme to obtain a total cost probability distribution cannot be done mathematically.

In Monte Carlo simulation, a random sample is taken from the probability distribution associated with each CER and each risk variable. Based on the functional form of the factor or CER, arithmetic operations are performed to obtain a single estimate of the cost of that Cost Breakdown Structure element.

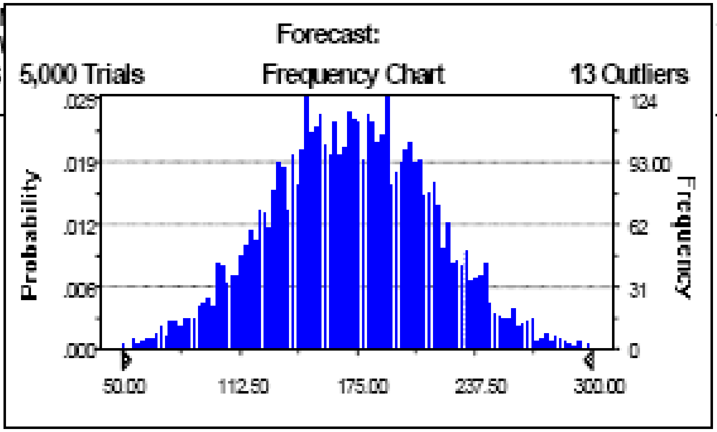
The procedure of random number selection and subsequent cost computation is then repeated thousands of times to develop a frequency histogram (or probability distribution) of total system cost.

MONTE CARLO SIMULATION

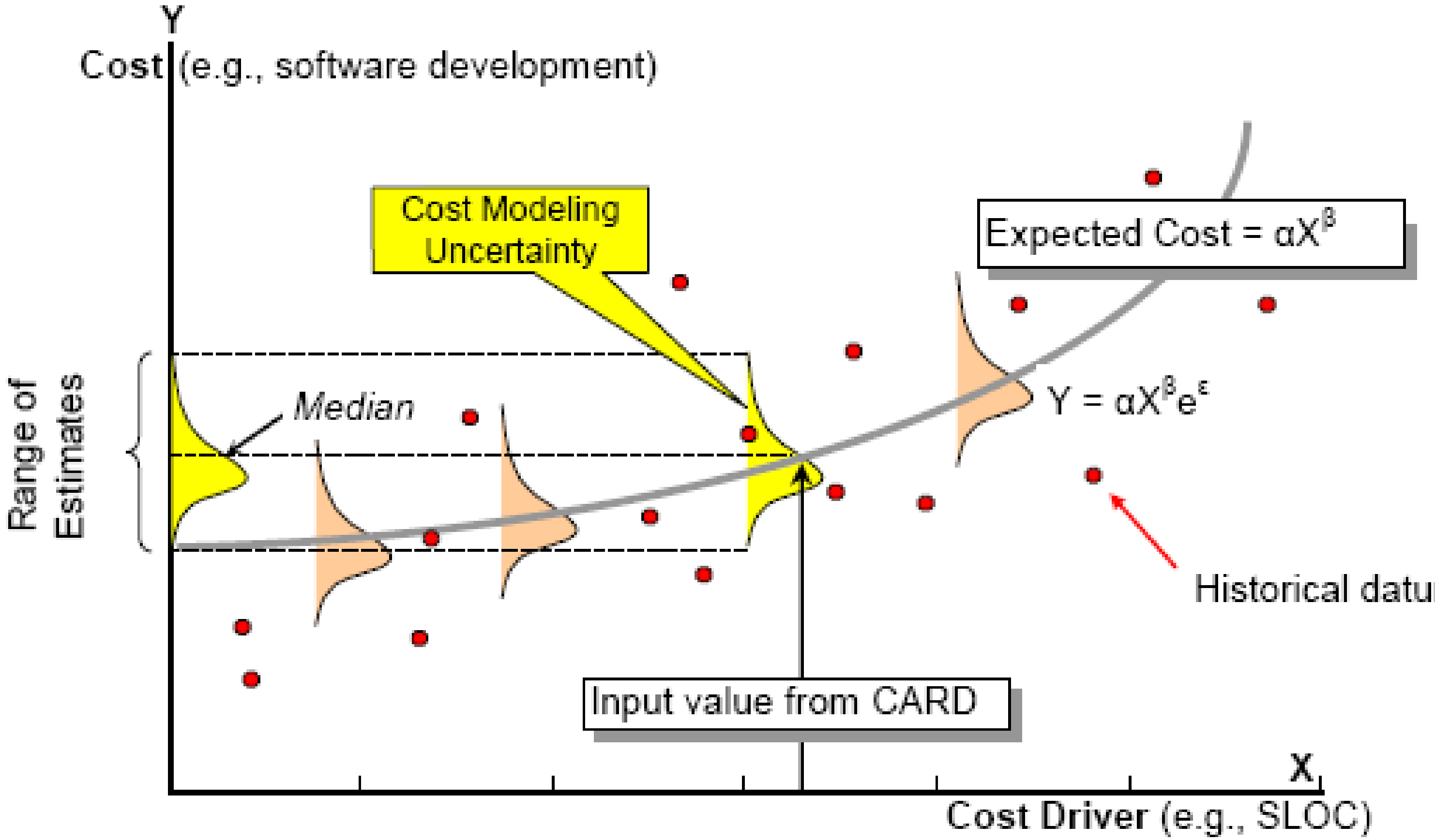
Crystal Ball Report
Simulation started on 1/3/01 at 18:24:18
Simulation stopped on 1/3/01 at 18:24:47

Forecast:

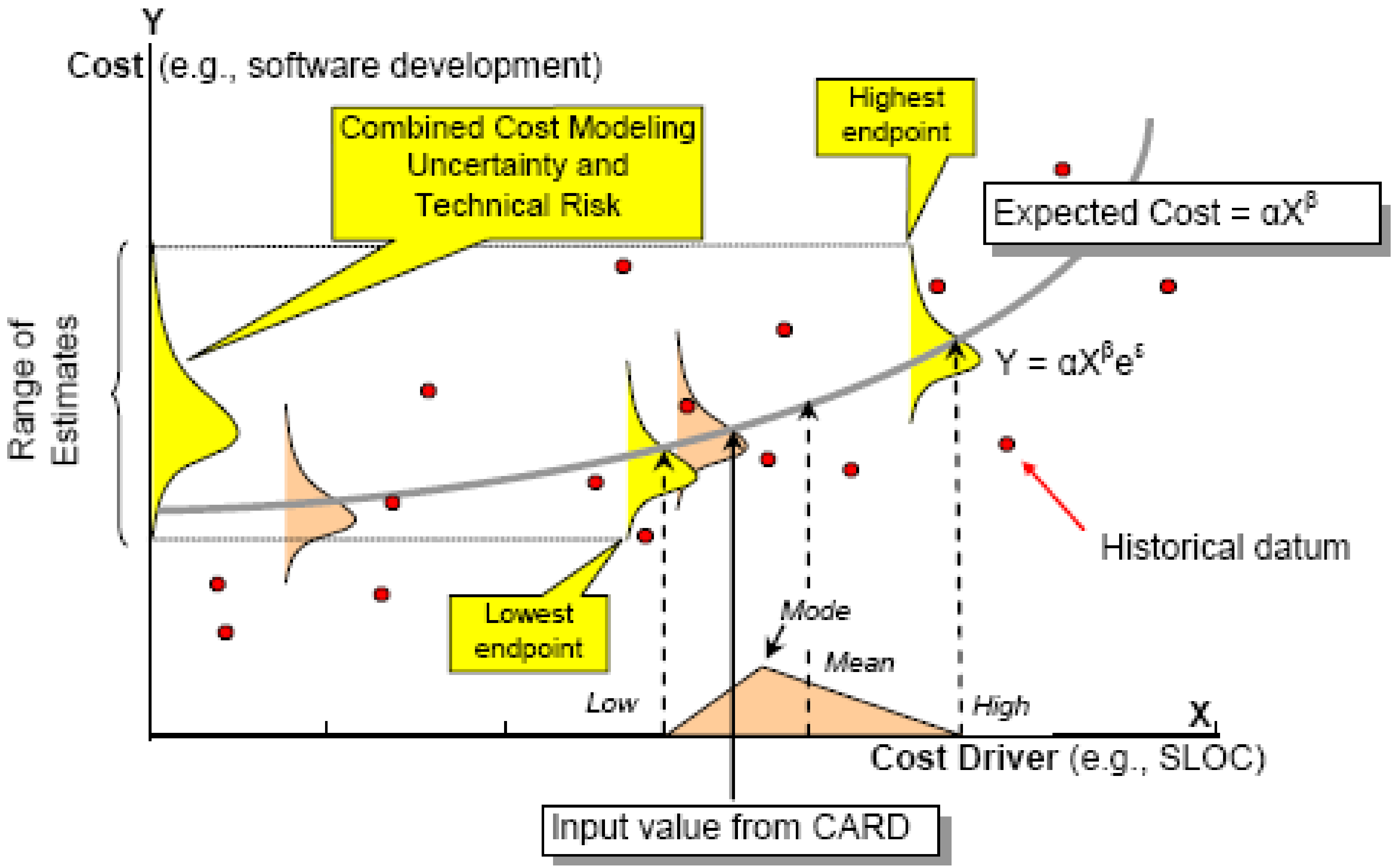
Statistics:	Value
Trials	5000
Mean	172.12
Median	172.33
Mode	---
Standard Deviation	43.32
Variance	1877.03
Skewness	0.01
Kurtosis	2.88
Coeff. of Variability	**0.25**
Range Minimum	22.38
Range I	.94
Range V	.56
Mean S	.61



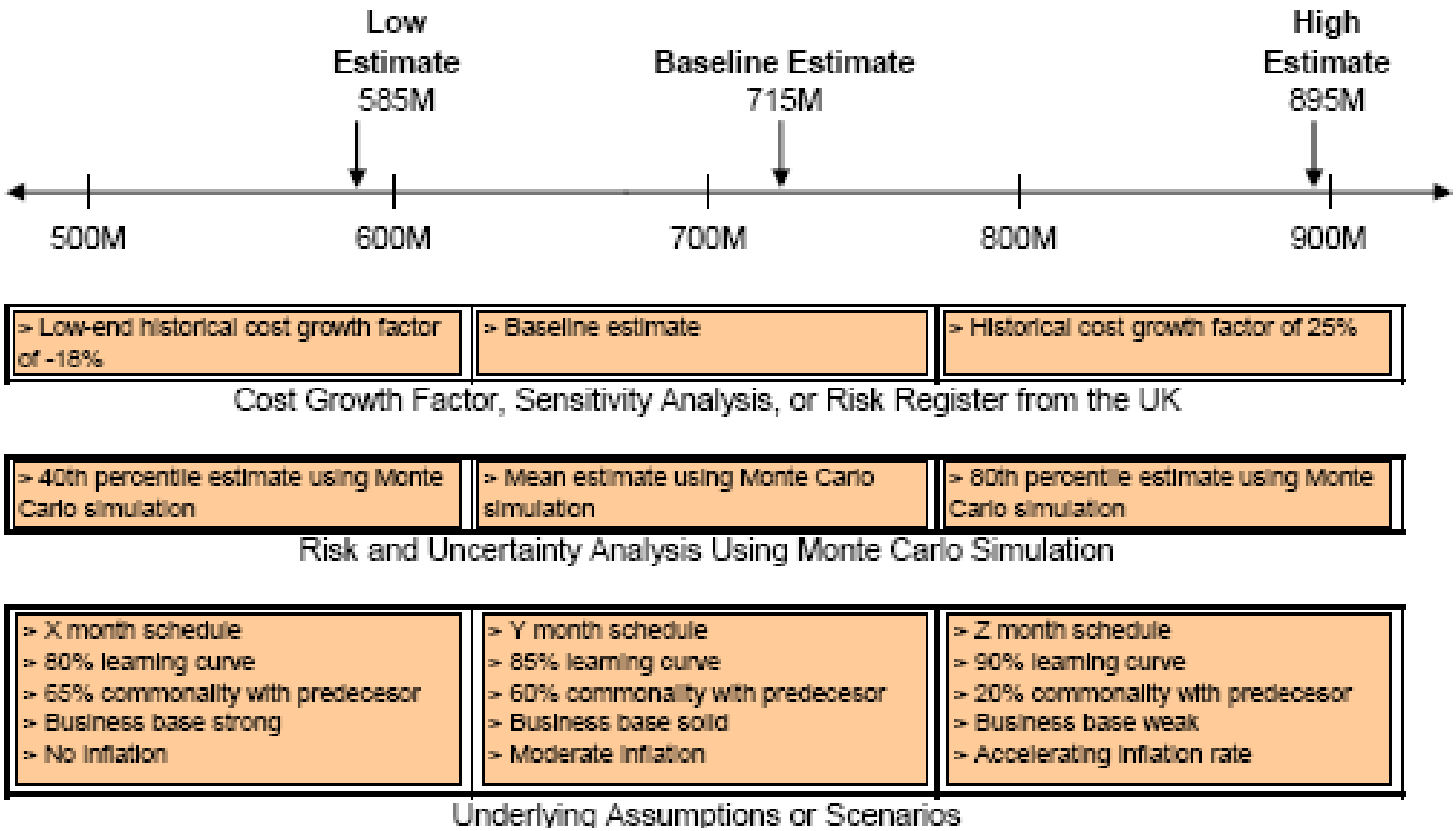
EXAMPLE OF BASELINE COST ESTIMATE



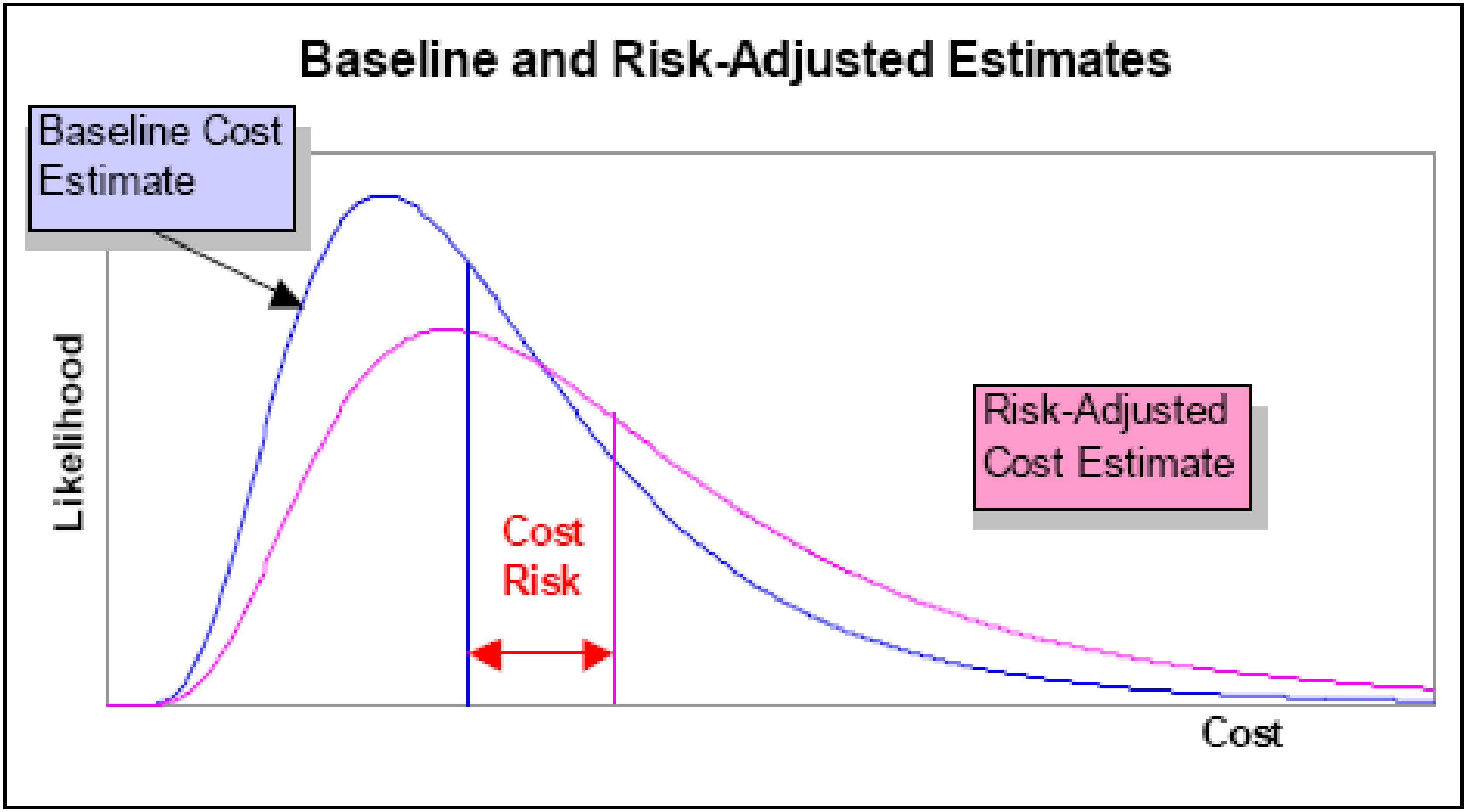
EXAMPLE OF RISK-ADJUSTED COST ESTIMATE



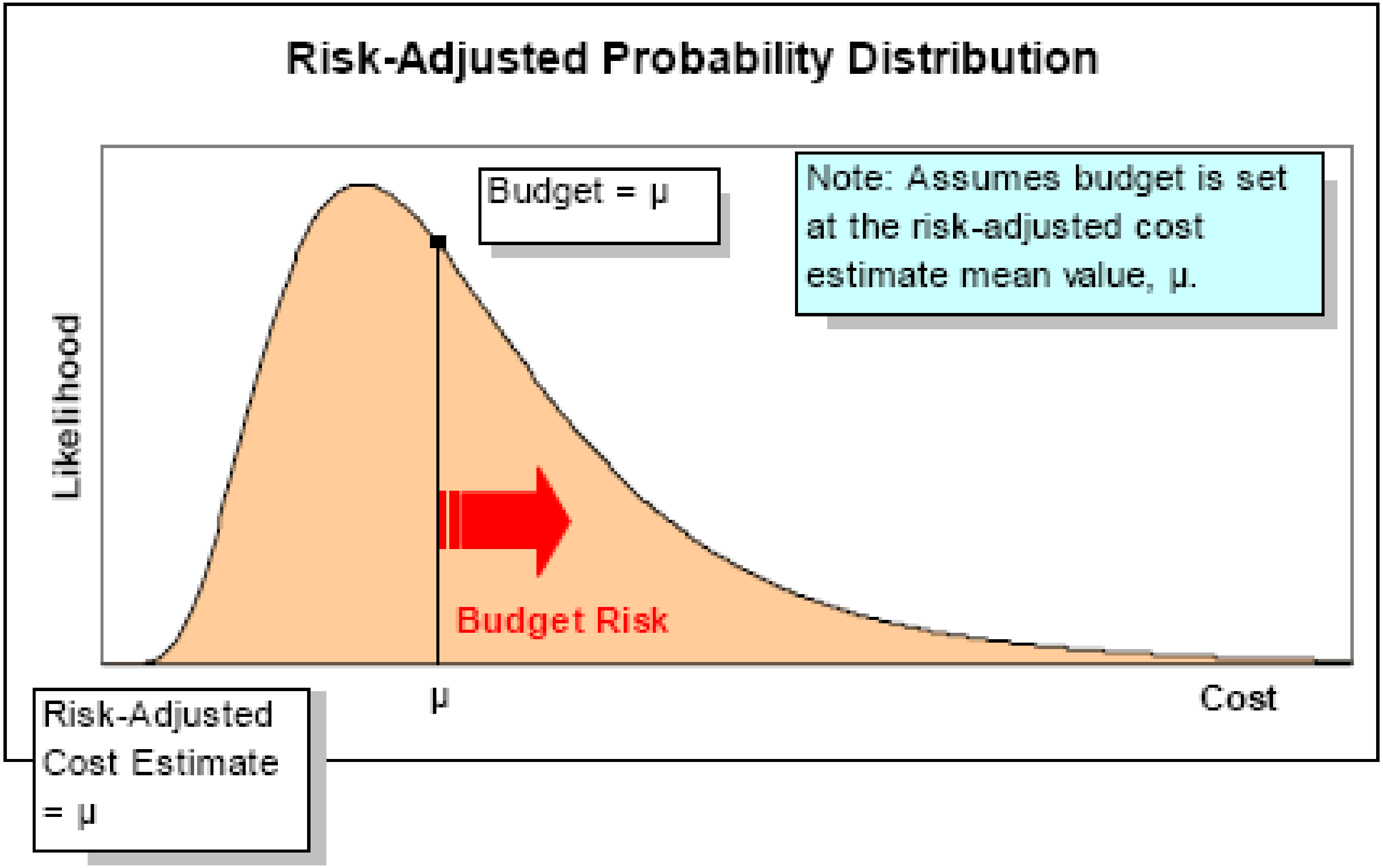
PRESENTATION OF COST ESTIMATING RISK ANALYSIS



BASELINE AND RISK-ADJUSTED COST ESTIMATES



BUDGET RISK ANALYSIS OUTPUT



QUANTITATIVE METHODS FOR COST RISK ANALYSIS

1. Quantitative cost risk analysis methods require gathering risk data, e.g. from in-depth interviews.
2. A Monte Carlo simulation approach is used to develop the possible costs of the acquisition programme under consideration.
3. Contingency reserve is taken into consideration. Using simulation, contingency reserve will be based on the risks identified and quantified; the accuracy of the results will depend on the accuracy of information developed during the risk analysis as well as the underlying estimate.
4. The estimation of likely programme costs enables decision makers to see clearly the cost implications of events that can influence the outcome of an acquisition program.

INTEGRATED COST-SCHEDULE RISK ANALYSIS (1)

While schedule risk has typically been neglected in cost risk assessments, only recently have the tools been available to include a full analysis of the impact of schedule uncertainty on the uncertainty in cost.

Monte Carlo simulation is the most commonly used approach to analysing the impact of multiple risks on the overall programme schedule or cost risk.

INTEGRATED COST-SCHEDULE RISK ANALYSIS (2)

Integrating cost and schedule risk analysis provides the most accurate information about cost risk and reveals the most important risks that affect cost, since some schedule risks have significant impact on costs.

The most effective mitigation of both schedule and cost risk comes from identifying both cost risks and schedule risks to the acquisition programme and mitigating those that are highest priority.