An Intuitive Application of Cost Risk Analysis to a Logistics Requirements Funding Summary (LRFS)

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Contents

Background and Overview

LRFS Cost Estimating Tool: Background

- The Uncertainty Modeling capability (UMC) is incorporated into the LRFS Cost Estimating Tool (CET)
- LRFS CET is a MS Excel based, user-friendly tool designed to allow program managers and logisticians to quickly generate LRFSs for all types of Marine Corps programs
- The CET includes a library of cost models for all the ILS disciplines and incorporates statutory and regulatory requirements
- The CET enables users to:
  - Provide a more efficient, effective and accurate means of developing LRFSs
  - Provide visibility of logistics support requirements
  - Inform resource and assessment sponsors of logistics support requirements
  - Serve as the format for presentation of support and associated funding requirements throughout program development at all acquisition milestone decision forums
  - Can be tailored to meet the program’s support objectives
  - Support LCCE, POM submission and budgetary decisions

Why include Uncertainty Analysis in an LRFS?

- **"Point estimates alone are insufficient for good decisions"**(1)
  - In a program's early phases, knowledge about how well technology will perform, whether the estimates are unbiased, and how external events may affect the program is imperfect
  - For management to make good decisions, the program estimate must reflect the degree of uncertainty, so that a level of confidence can be given about the estimate
- The difference between Risk and Uncertainty
  - Risk is the chance of loss or injury. In a situation that includes favorable and unfavorable events, risk is the probability that an unfavorable event will occur
  - Uncertainty is the indefiniteness about the outcome of a situation. It is assessed in cost estimate models to estimate the probability that a specific funding level will be exceeded

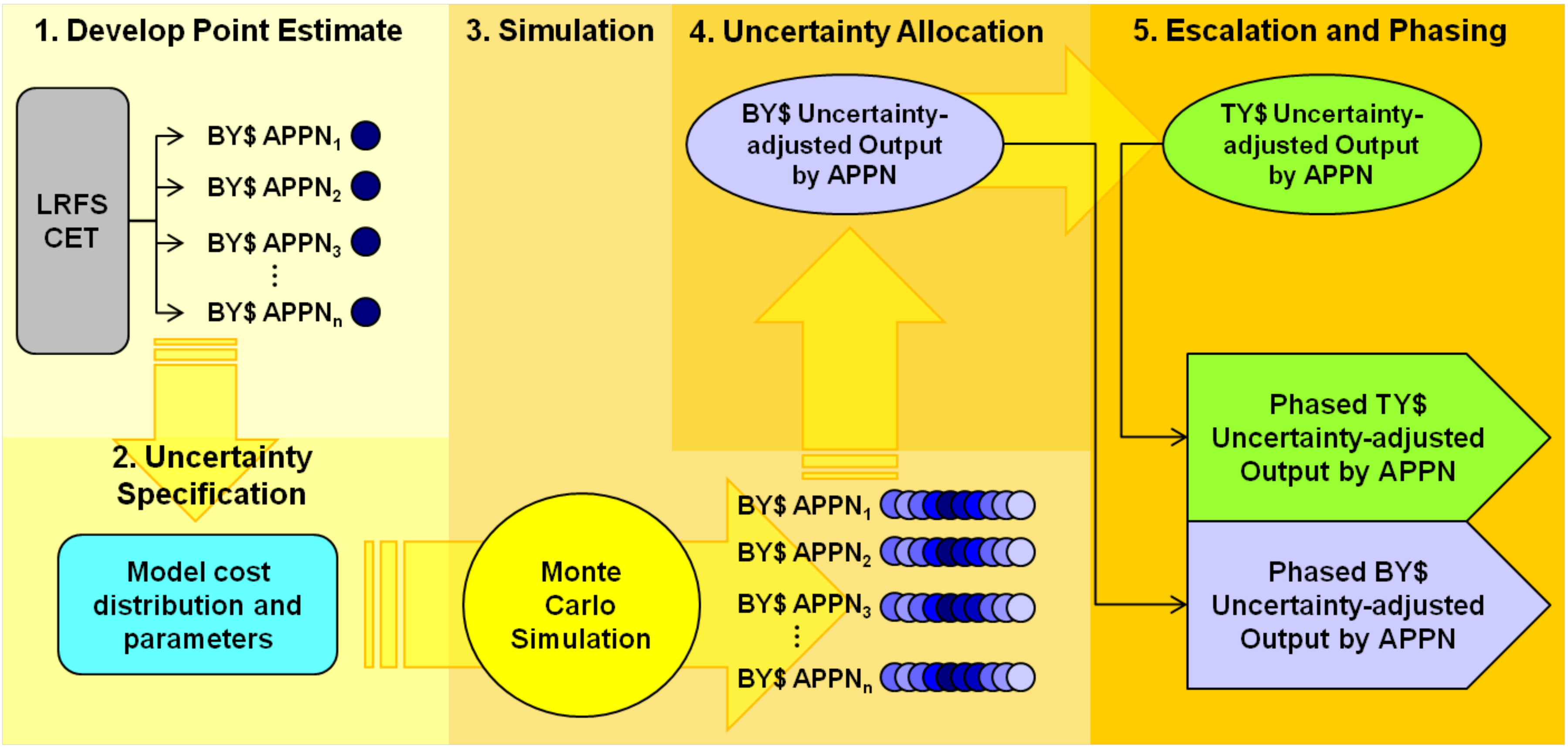
(1) GAO Cost Estimating and Assessment Guide GAO–09–3SP

LRFS CET Uncertainty Modeling Capability: Overview

- The purpose of the CET's UMC is to provide an intuitive process for logisticians to produce uncertainty adjusted LRFS estimates
  - Allow logisticians to produce uncertainty adjusted estimates that are backed by USMC and DoD standards
  - Report uncertainty-adjusted outputs at varying confidence levels for improved budgeting and decision making
- UMC's simulation engine is entirely MS Excel based
  - All statistical analysis is performed by MS Excel functions
  - Simulation, allocation, and phasing processes performed by Visual Basic for Applications (VBA)
- UMC is designed to be portable within the USMC Program Offices and MARCORSYSCOM
  - Simulation capabilities are contained within a MS Excel workbook output by the LRFS CET
  - Can be distributed independent of the LRFS CET and only requires MS Excel version 2007

Approach

UMC Approach: Uncertainty Modeling Process Map



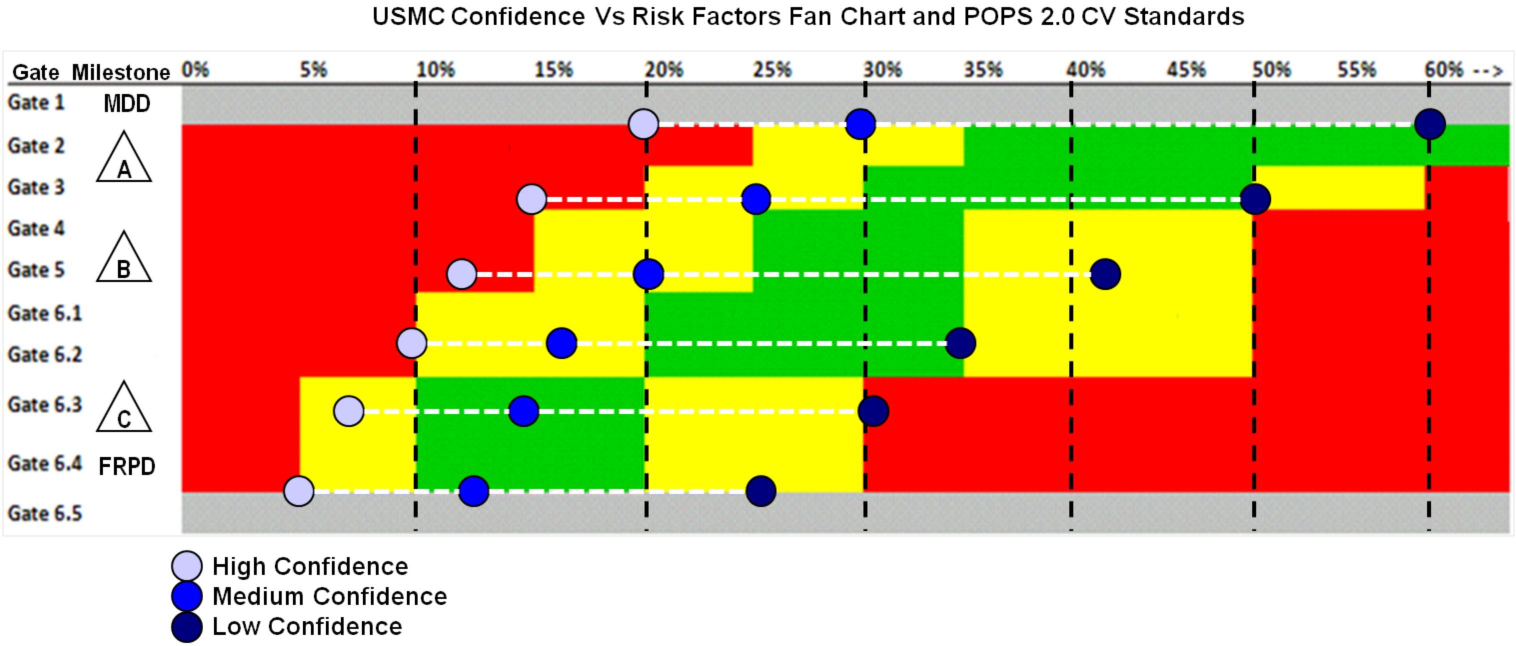
1. Develop Point Estimate: LRFS CET Outputs

- The necessary inputs for the UMC Monte Carlo (MC) simulation process are **Point Estimate** (PE) and **Coefficients of Variation** (CV)

- The **Point Estimates** is the standard output of the LRFS CET
  - Generated with the aid of empirical cost data and CERs
  - Refined by logisticians and program subject matter experts
  - Developed in Base Year dollars and escalated to adjust for inflation and outlay

- Default **Coefficients of Variation** are provided by the LRFS CET based on program maturity
  - Default CVs derived from USMC Risk Standards Fan Chart (slide #21) and POPS 2.0 CV Standards (slide #22) (more complete discussion on slides 7 and 8)
  - LRFS CET interface allows logisticians to specify a confidence level of ***Low***, ***Medium***, or ***High*** to customize default CVs at the module level
  - Within the UMC workbook CVs can be customized for every element that is subject to simulation at the discretion of the user

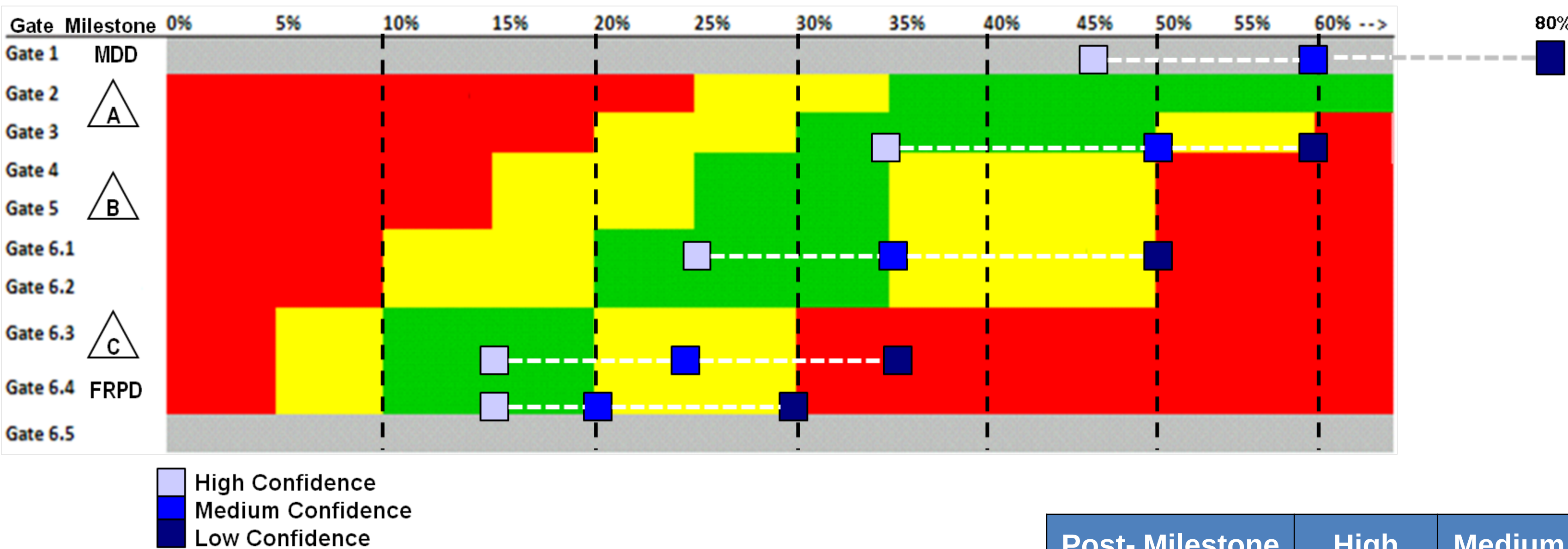
2. Uncertainty Specification: Relating CV to Program Maturity



- POPS 2.0 standards prescribe estimate health based on CV and program maturity, whereas the Risk Factors Fan Chart (RFFC) relates confidence level to CV by program maturity
- The figure above denotes the RFFC superimposed on the POPS 2.0 CV standards chart
  - The CVs corresponding to high confidence recommended by the RFFC are shown to be overly optimistic by POPS standards

2. Uncertainty Specification: Relating CV to Program Maturity

CETUM Default CV Selection and POPS 2.0 CV Standards



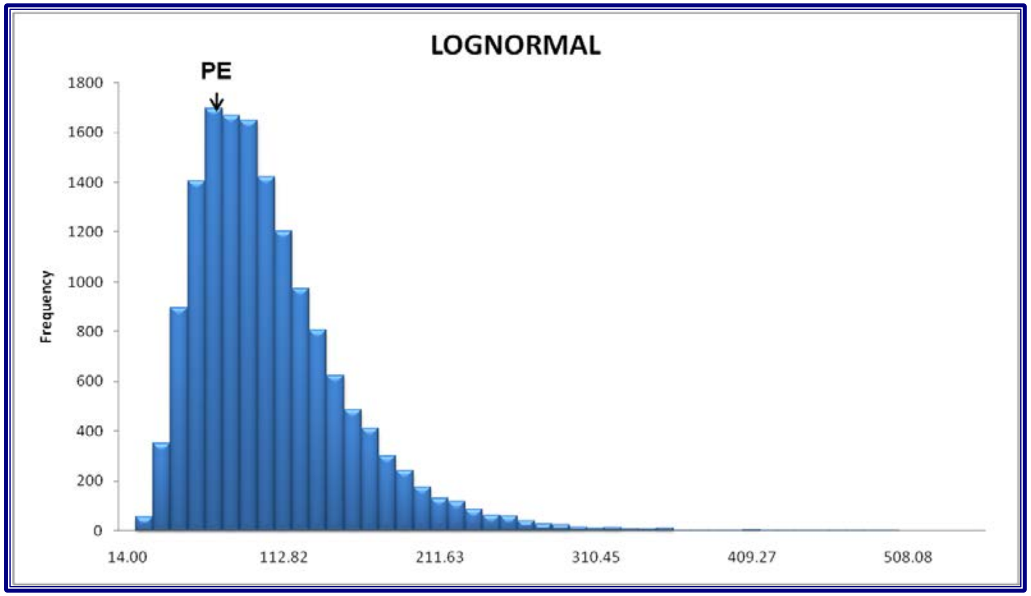
- The LRFS CET requires logisticians to enter dates for MDD, Milestones A,B,C and FRPD
  - The time of the estimate relative to specified milestone dates is used to interpret program maturity
  - UMC's CV selection is more pessimistic than the CVs prescribed by the RFFC

Post- Milestone	High	Medium	Low
MDD	45%	60%	80%
A	35%	50%	60%
B	25%	35%	50%
C	15%	25%	35%
FRPD	15%	20%	30%

UMC Default CV by Program Maturity

2. Uncertainty Specification: Distribution Modeling

- UMC models each child level element's *total program cost* as a **Lognormal** distribution
  - The Lognormal distribution can increase without limits but cannot fall below zero; most of its values occur near the mode
  - Typical applications include labor rate CERs and factor methods
  - The LRFS CET's CER database consists of 75% labor based models, and 25% factor based models
- The PE position is modeled as the mode
  - The mode of a discrete lognormal distribution is the value at which its probability mass function takes its maximum value
  - In other words, it is the value that occurs with the greatest frequency



Histogram of Lognormal distribution; mode = 100, CV = .30

3. Simulation: Generating Correlated Random Variables

- UMC relies on MS Excel's built in random number generator (RNG) to sample RVs ~ U(0,1)
  - The RNG in MS Excel versions 2003 and later has been verified as a quality RNG by passing the DIEHARD tests as well as additional tests developed by the NIST(1)
- UMC simulates *defined correlation* via the Iman-Conover Method
  - Iman-Conover method induces rank correlation through the creation of a reference distribution that has exactly the desired linear correlation of a target correlation matrix
  - The RV matrix is then re-ordered to have the same rank order as the reference distribution
  - The result is a RV sample with rank correlation equal to the reference distribution which has the desired linear correlation
- UMC's target correlation matrix was developed through *subjective correlation*
  - Pearson's correlation coefficient (ρ) equal to 30% applied to all elements
  - ρ = 75% applied to elements with documented or perceived interdependencies

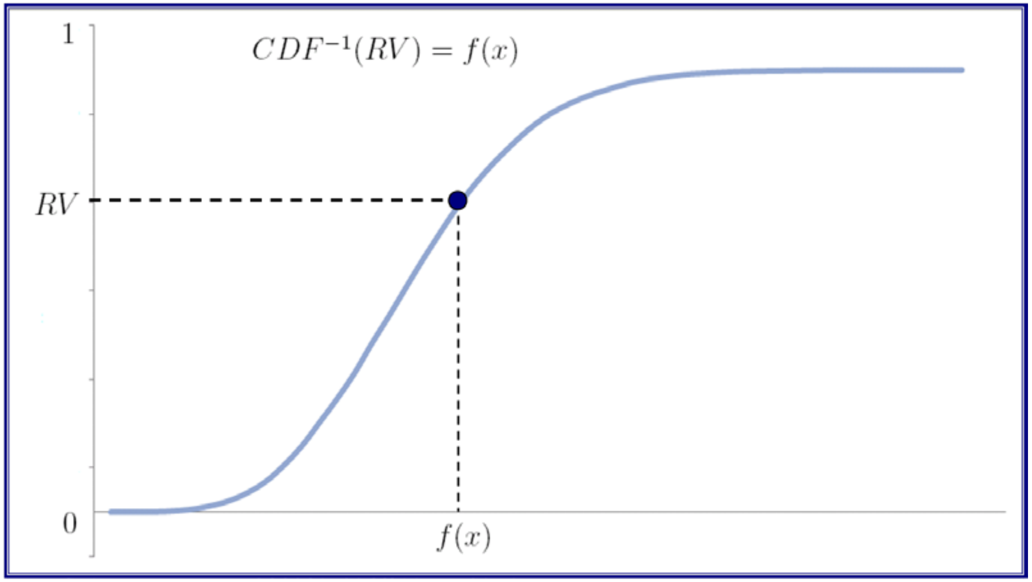
	Positive Correlation	Negative Correlation
Uncorrelated	0%	0%
Small Amount of Correlation	30%	-30%
Large Amount of Correlation	75%	-75%

Subjective Correlation: SSCAG Space Systems Cost Risk Handbook

(1) http://support.microsoft.com/kb/828795

3. Simulation: Distribution Sampling

- UMC transforms correlated RVs ~ U(0,1) to the LogNormal distribution via the **Inverse CDF technique** (CDF^{-1})
  - Accomplished via the MS Excel Function "=LogInv()" requiring parameters *Mean* and *StDev*
  - The parameters *Mean* and *StDev* are analytically derived from the PE developed by the LRFS CET and the CV that corresponds to the user selected confidence level (Math Appendix I, slide #23)
- Once simulated, child element distributions are combined to form parent level distributions
  - Parent's statistical characteristics are defined by the combined effects of children distributions

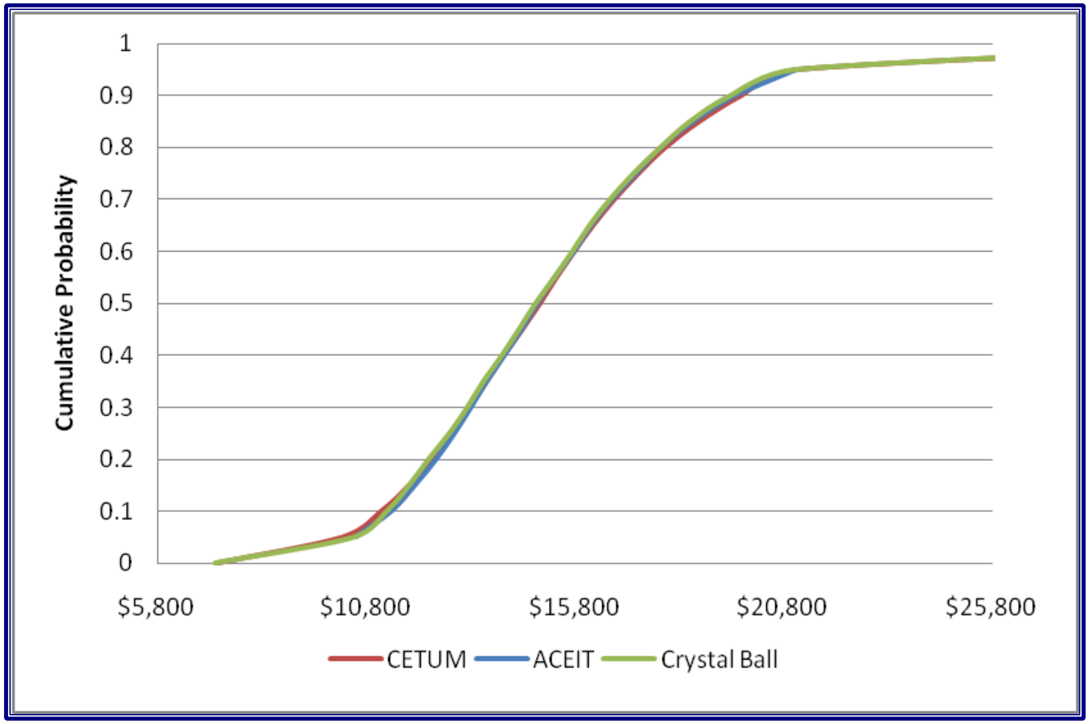


CDF^{-1} Technique Mapping RV~U(0,1) to CDF

3. Simulation: Initial Benchmarking

- The LRFS CET module representing Manpower, Personnel and Training (MPT) was simulated for benchmarking purposes
  - MPT is a good test candidate because it is one of the largest modules and contains the most complex parent-child hierarchy
- UMC generated percentiles and descriptive statistics are within ~1% of the results produced by ACEIT and Crystal Ball (CB)

MPT Project Total BY$K



Common Descriptive Statistics BY$K

	ACEIT	CB	UMC	%Δ ACEIT	%Δ CB
Mean	$15,239	$15,202	$15,220	0%	0%
StDev	$3,296	$3,326	$3,343	0%	0%
CV	22%	22%	22%	0%	0%

MPT Project Total PE = $1390K

Test Assumptions:
MPT module's CES element's project level PEs were simulated
Each element modeled as LogNormal distribution; PE position = mode
CV = .30 for all elements, blanket correlation of .50 defined
5K LHC trials run in ACEIT, 5K MC trials run in CB and UMC

4. Uncertainty Allocation

- Uncertainty confidence levels are applied at the project total level, and then CES elements are adjusted
  - Confidence levels are **not** additive
- UMC recursively prorates child values according to weighted averages of child StDVs to ensure summation to the correct parent confidence level (Math Appendix II, slide #24)
  - UMCs allocation process follows cost industry standards and best practices (1)
- UMC calculates the 20th ,30th ,40th ,50th ,60th ,70th, and 80th percentiles for the project level total cost and stores the allocated values for the CES elements

Total	800
Module 1	200
1.1	85
1.2	130
Module 2	500
2.1	225
2.2	300
Module 3	118
3.1	45
3.2	68

UMC uses Multi-Tiered Recursive Allocation

(1)Sandberg, J. Cost Risk Allocation Objectives, Tendencies and Limitations, ISPA/SCEA Conference 2007

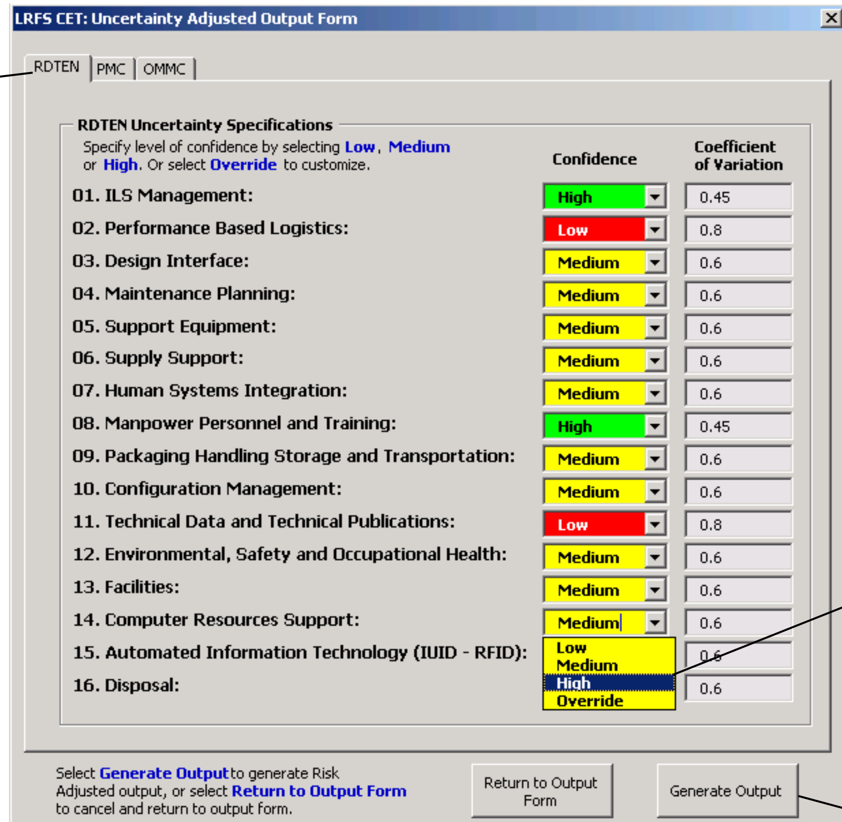
5. Escalation and Phasing

- The LRFS CET includes adjustment factors for inflation and outlays
  - Factor tables taken from *Navy Cost Analysis Inflation Workbook*
- Factor tables are included in the UMC workbook and allow for the adjustment of allocated BY$ confidence levels to reflect TY$
- Allocated confidence levels for BY$ and TY$ are phased over the system life for each CES element
  - Phasing factors are determined by the ratio of yearly PE to total project PE
  - The phased estimates sum to the correct yearly total confidence level as a result of the allocation process

Interface

UMC: LRFS CET Interface

Within the LRFS CET, users are allowed to specify confidence level by module for each APPN with an associated cost



Intuitive confidence level specification: “High”, “Medium”, or “Low”

Once confidence levels are specified, an independent “Uncertainty Workbook” is created

UMC: Uncertainty Workbook Interface

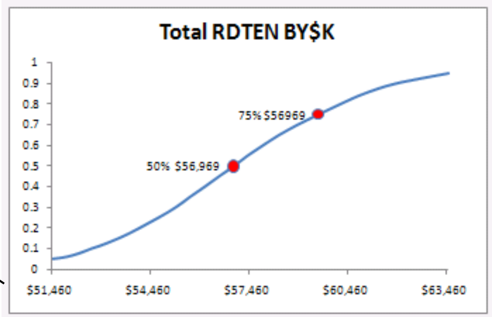
Cost values for all CES elements stored at multiple confidence levels by APPN

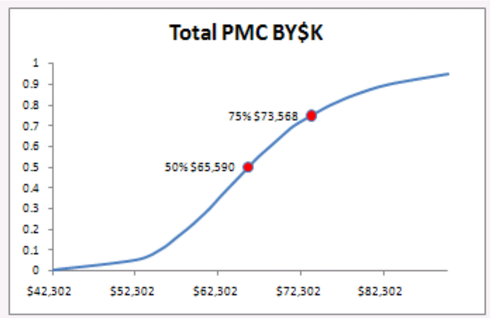
Confidence Level Displayed: Point Estimate

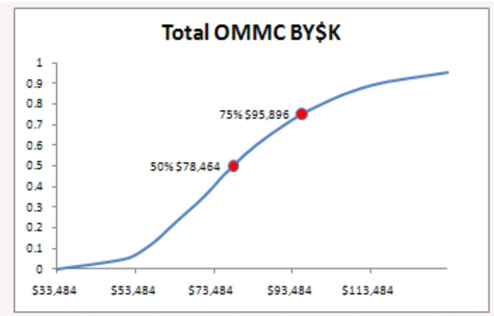
Point Estimate
Mean
20%
30%
40%
50%
60%
70%

Element		TOTAL	FY11	FY12	FY13
LRFS USMC		$49,095	$0	$4,741	$1,917
ILS Management		$7,776	$0	$843	$645
Performance Based Logistic		$1,741	$0	$125	$0
Design Interface		$8,875	$0	$577	$577
Maintenance Planning		$1,602	$0	$243	$158
Support Equipment		$1,319	$0	$437	$303
Supply Support		$2,924	$0	$0	$0

Customizable cumulative probability charts by APPN





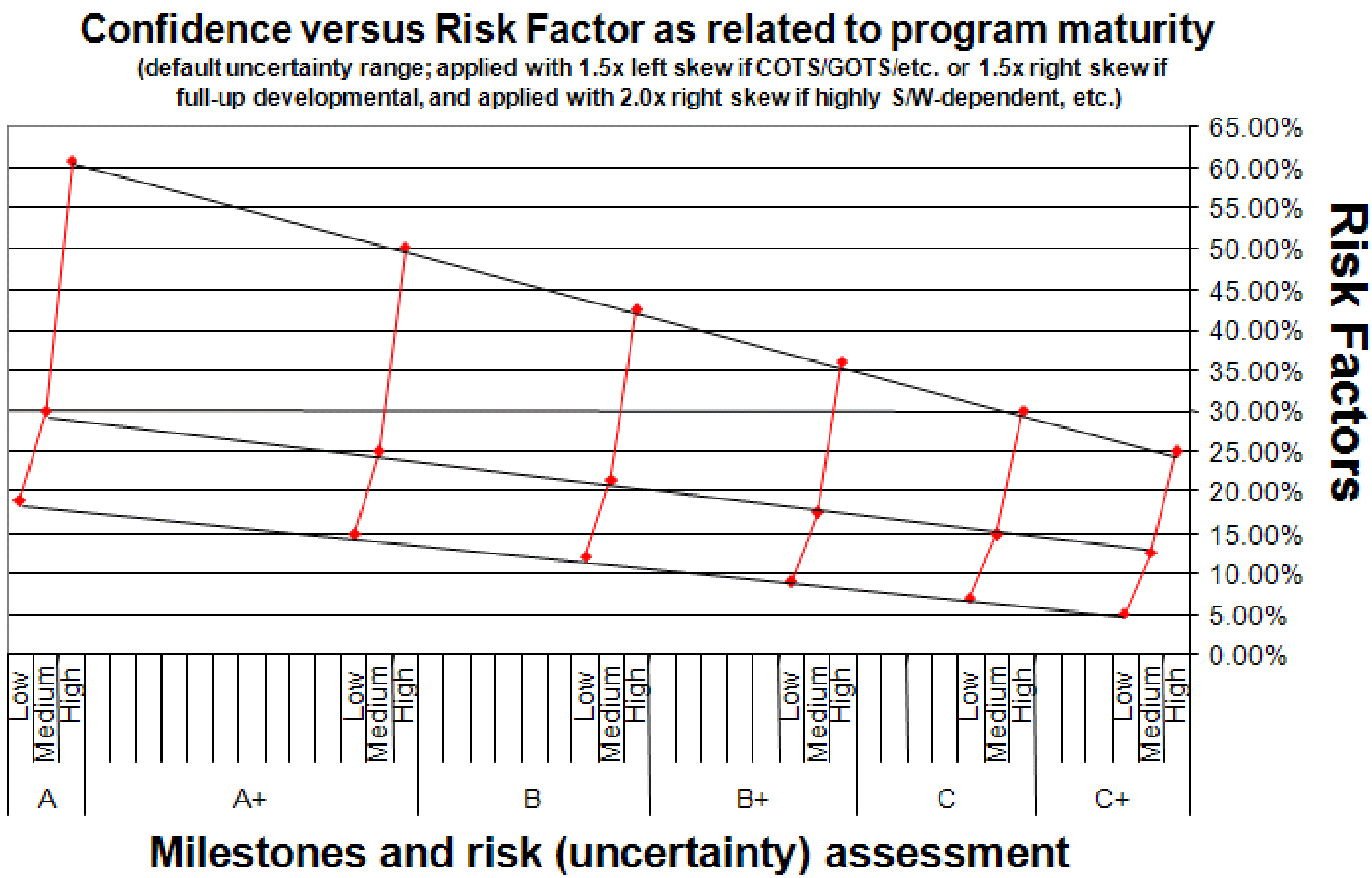


Summary Statistics BY$K	RDTEN	PMC	OMMC
Mean	$57,169	$67,994	$83,661
StDeV	$3,675	$12,199	$27,008
CV	6%	18%	32%

Backup Slides

- Figures
- Math Appendices

USMC Risk Standards Fan Graph



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POPS 2.0 CV Standards

Coefficient of Variation (CV) standards

Gate	POPS 2.0 measure	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60% -->
Gate 1														
Gate 2	2.8.5	CV < 25%					25% < CV < 35%		35% < CV					
Gate 3	3.8.5	CV < 20%				20% < CV < 30%		30% < CV < 50%				50% < CV < 60%		60% < CV
Gate 4	4.8.5	CV < 15%			15% < CV < 25%		25% < CV < 35%		35% < CV < 50%			50% < CV		
Gate 5	5.8.5	CV < 15%			15% < CV < 25%		25% < CV < 35%		35% < CV < 50%			50% < CV		
Gate 6.1	6.ibr.8.5	CV < 10%		10% < CV < 20%		20% < CV < 35%			35% < CV < 50%			50% < CV		
Gate 6.2	6.cdr.8.5	CV < 10%		10% < CV < 20%		20% < CV < 35%			35% < CV < 50%			50% < CV		
Gate 6.3	6.cpd.8.5	CV < 5%	5% < CV < 10%	10% < CV < 20%		20% < CV < 30%		30% < CV						
Gate 6.4	6.frp.8.5	CV < 5%	5% < CV < 10%	10% < CV < 20%		20% < CV < 30%		30% < CV						
Gate 6.5														

Math Appendix I: Deriving LogNormal CDF^{-1} Parameters

Let $Y = e^X$ with $X \sim N(\mu, \sigma^2)$. Therefore, $Y \sim Ln(\alpha, \beta^2)$ such that:

$$\alpha = e^{\mu + \frac{1}{2}\sigma^2} \qquad \text{Eq. (1)}$$

$$\beta = \left(\left(e^{\sigma^2} - 1\right)e^{2\mu + \sigma^2}\right)^{1/2} \qquad \text{Eq. (2)}$$

To solve for σ we note that the square of the coefficient of variation of Y is equal to:

$$CV_Y = \left(\frac{\beta}{\alpha}\right)^2 = e^{\sigma^2} - 1 \qquad \text{Eq. (3)}$$

Solving Eq. (3) for σ in terms of α and β yields:

$$\sigma = \ln(\alpha) - \frac{1}{2}\ln\left(\left(\frac{\beta}{\alpha}\right)^2 + 1\right) \qquad \text{Eq. (4)}$$

The UMC process simulates Y via the MS Excel function LOG.INV with arguments μ_x and σ_x. The known parameters for Y are the point estimate (PE_Y) and the coefficient of variation (CV_Y). Given the known parameters, and by use of Eq. (4) we calculate the required arguments, μ_x and σ_x, as follows:

$$PE_y = e^{\mu_x - \sigma_x^2} \Rightarrow \mu_x = \ln\left(PE_y\left(CV_y^2 + 1\right)\right)$$

$$\sigma_x = \ln(CV_Y^2 + 1)^{\frac{1}{2}}$$

Math Appendix II: Uncertainty Allocation Overview

(1) First we calculate the target confidence level (TCL) values for a parent and its child elements and define Δ_P:

$$\Delta_P = C_P - \sum_{i}^{N_P} C_{Pi}$$

Where C_P equals the parent TCL value, N_P equals number of child elements, and C_{P_i} is TCL value of the ith child. Therefore, Δ_P is the amount by which we will need to adjust child element TCL values to ensure summation to the correct parent TCL value.

(2) Next we prorate Δ_P among child elements to get adjusted cost for child element i, denoted here by P_i.

$$P_i = C_{pi} + \Delta_P \frac{\sigma_i}{\sum_j \sigma_j}$$

Where σ_i is the standard deviation of child i, and $\sum_j \sigma_j$ is the sum of the standard deviations for all child elements.

(3) For each child element that is also a parent, we repeat the process by distributing the adjusted cost, P_i, among i's child elements. Analogous to step 1 we define Δ_{P_i}:

$$\Delta_{P_i} = P_i - \sum_{i}^{N_P} C_{Pi}$$

(4) We continue to iterate steps 1 and 2 until Δ_P is distributed to the lowest level on the parent-child hierarchy.

(1)Sandberg, J. Cost Risk Allocation Objectives, Tendencies and Limitations, ISPA/SCEA Conference 2007

Questions?

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