Impact of Correlating CER Risk Distributions on a "Realistic" Cost Model

Selected "Best Paper" Risk Track ISPA/SCEA Jun 2003

Addresses "Correlation Accuracy in ACEIT RI$K Simulations"

(includes additional slides addressing questions raised at the SSCAG presentation)

Alfred Smith – General Manager Software Products Services Group

Dr. Shu-Ping Hu – Principal Analyst

Tecolote Research Inc

Overview

- Introduction, “issues” associated with a simplistic case study.
- Introduce a “realistic” cost model
  (Complex CERs, functional relationships, CER risk, Input Risk, correlation)
- Choosing Risk Distributions, Bounds and Penalty Factors
- **Theoretical Basis for ACE Correlation Algorithm**
- Introduce the Risk Distribution Correlation Study
- ACE Correlation Utility: calculates the risk correlation matrix ***achieved*** in the ACE risk simulation.
- Compare ACE **correlation matrix input** to **correlation matrix output**
- Cost impact of applying correlation
- Concluding remarks

© 2003 Tecolote Research, Inc

Introduction

Papers addressing risk analysis frequently use a very simple cost model to illustrate a point. These models often:

- Merely sum a dozen or so numbers, mostly of similar magnitude.
- Ignore phasing, inflation, learning, functional relationships etc.
- Generally do not contain complex cost estimating relationships.
- Ignore the impact of correlating CER inputs.

© 2003 Tecolote Research, Inc

Case Study Page CE V – 80
SCEA Training Manual

ACE 6.0 - [60Beta1SCEACaseStudyJun2003.acw - RI$K (BY2003 $K)]

File Edit Workscreen Input Calc Reports Tools Window Help

RI$K | MS Sans Serif | 8 | Black

12 | Electronic System

	WBS/CES Description	Unique ID	Equation / Throughput	Distribution Form	Low or Low %	Low Interpret	High or High %	High Interpr
12	Electronic System							
13	Prime Mission Product	PMP	12.5	Normal	32%	10	168%	90
14	System Eng & Prog Management	SEPM	.5*PMP					
15	System Test and Evaluation							
16	Sys Test and Eval		.25*PMP+SEPM/8					
17	Management Reserve		(0.6 + 1.0)/2	Uniform	.6	0	1	100
18	Data and Technical Orders		0.1 * PMP					
19	Site Survey and Activation		6.6	Triangular	5.1	0	12.1	100
20	Initial Spares		0.1 * PMP					
21	System Warranty		(0.9+1.3)/2	Uniform	.9	0	1.3	100
22	Early Prototype Phase		1.5	Triangular	1	0	2.4	100
23	Operations Support		1.2	Triangular	.9	0	1.6	100
24	System Training		0.25*PMP					

Ready

PMP is a throughput.

PMP drives 5 other cost elements, 72% of the entire estimate.

Remaining elements are throughputs (independent).

© 2003 Tecolote Research, Inc

SSCAG Risk Subgroup

SCEA Case Study Correlation

Microsoft Excel - ACE SCEA Case Study Correlation Utility Beta1a.xls

File Edit View Insert Format Tools Data Window Help Acrobat

Favorites C:\Sessions\SCEAISPA\ACE SCEA Case Study Correlation Utility CloseFile SetSheets LoadHR

D3 = =CORREL('Result from Each Iteration'!P3:P10003,'Result from Each Iteration'!Q3:Q10003)

	A													
1	**WBS:**	Electronic System	**Prime Mission Product**	**System Eng & Prog Management**	System Test and Evaluation	**Sys Test and Eval**	Management Reserve	**Data and Technical Orders**	Site Survey and Activation	**Initial Spares**	System Warranty	Early Prototype Phase	Operations Support	**System Training**
2	Electronic System	100%	99%	99%	99%	99%	1%	99%	11%	99%	-1%	3%	0%	99%
3	**Prime Mission Product**		100%	100%	100%	100%	0%	100%	0%	100%	-2%	1%	-1%	100%
4	System Eng & Prog Management			100%	100%	100%	0%	100%	0%	100%	-2%	1%	-1%	100%
5	System Test and Evaluation				100%	100%	6%	100%	0%	100%	-2%	1%	-1%	100%
6	Sys Test and Eval					100%	0%	100%	0%	100%	-2%	1%	-1%	100%
7	Management Reserve						100%	0%	0%	0%	2%	-1%	0%	0%
8	Data and Technical Orders							100%	0%	100%	-2%	1%	-1%	100%
9	Site Survey and Activation								100%	0%	0%	0%	0%	0%
10	Initial Spares									100%	-2%	1%	-1%	100%
11	System Warranty										100%	-1%	0%	-2%
12	Early Prototype Phase											100%	1%	1%
13	Operations Support												100%	-1%
14	System Training													100%

Configuration and Help / Result from Each Iteration / Correlation Results

Ready

Elements in grey are a linear function of PMP.

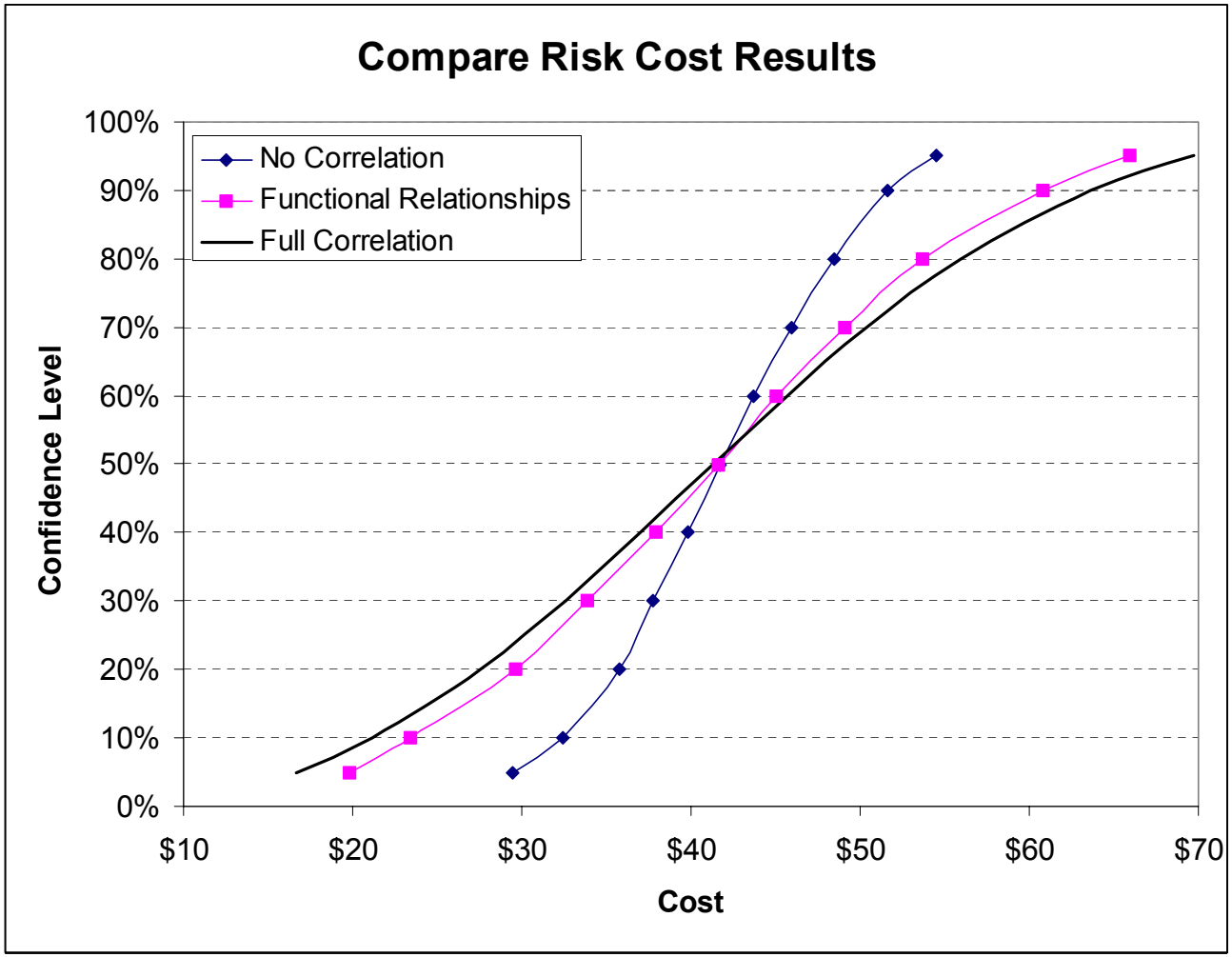
ACE Correlation Utility records the results of each Risk iteration and uses the Excel function "CORREL" to calculate the correlation between cost elements.

Note that the entire correlation matrix is generated correctly.

TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

© 2003 Tecolote Research, Inc

Compare Risk Cost Results



© 2003 Tecolote Research, Inc

Case Study Page CE V – 80 SCEA Training Manual

ACE 6.0 - [60Beta1SCEACaseStudyJun2003.acw - BY RI$K Report (FY2003 K, RIK Statistics, Ca...

File Edit Calc Tools Window Help

	WBS/CES	Cost	Mean	Std Dev	5.0% Level	25.0% Level	50.0% Level	75.0% Level	95.0% Level
27	** Functional Relationship								
28	Electronic System	39.481 (44%)	42.026	14.038	19.718	31.734	41.557	51.439	66.095
29	Prime Mission Product	12.500 (48%)	12.962	6.167	3.102	8.482	12.747	17.129	23.505
30	System Eng & Prog Manager	6.250 (48%)	6.481	3.083	1.551	4.241	6.373	8.565	11.753
31	System Test and Evaluation	4.706 (49%)	4.851	1.931	1.772	3.438	4.779	6.158	8.147
32	Sys Test and Eval	3.906 (48%)	4.051	1.927	0.969	2.650	3.983	5.353	7.345
33	Management Reserve	0.800 (50%)	0.800	0.115	0.620	0.700	0.800	0.900	0.980
34	Data and Technical Orders	1.250 (48%)	1.296	0.617	0.310	0.848	1.275	1.713	2.351
35	Site Survey and Activation	6.600 (21%)	7.933	1.505	5.825	6.726	7.713	8.997	10.711
36	Initial Spares	1.250 (48%)	1.296	0.617	0.310	0.848	1.275	1.713	2.351
37	System Warranty	1.100 (50%)	1.100	0.115	0.920	1.000	1.100	1.200	1.280
38	Early Prototype Phase	1.500 (36%)	1.633	0.290	1.187	1.418	1.606	1.839	2.149
39	Operations Support	1.200 (43%)	1.233	0.143	1.003	1.129	1.226	1.335	1.482
40	System Training	3.125 (48%)	3.240	1.542	0.776	2.120	3.187	4.28	

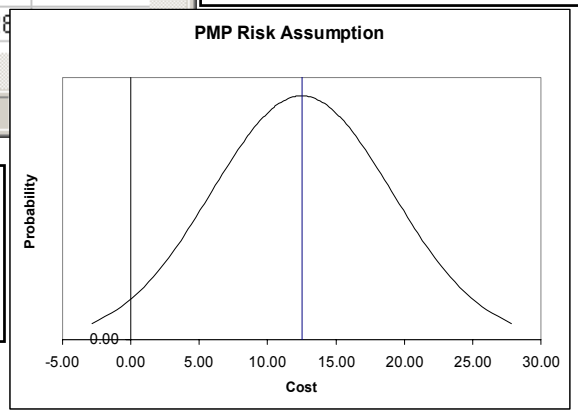
Ready

ACE functional relationships generates the case study correlations.

Case study result at 95% is $51.

ACE result at 95% is $66….a 27% increase? Why?

The distribution on the PMP throughput is so large, the left tail goes negative. ACE truncates at zero. Crystal Ball has an option to do so.



© 2003 Tecolote Research, Inc

Introduction

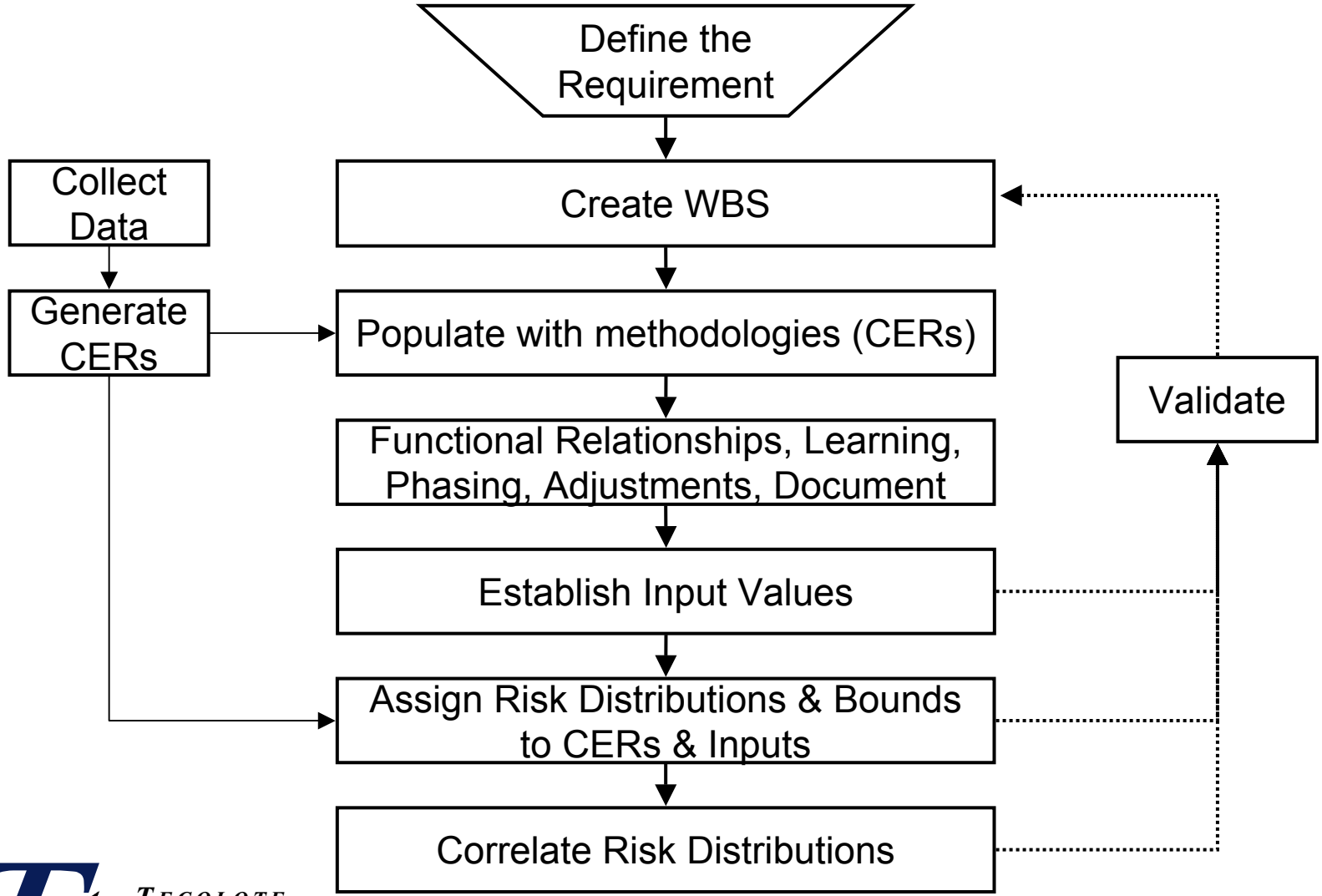
In this paper, we use a more realistic cost model that:

- Contains linear, non-linear, and factor CERs with inflation/phasing impacts.
- Has over 30 elements and as many input variables
- Has a realistic spread of cost across the elements

- We also introduce a utility that measures the correlation actually achieved in the risk simulation.

© 2003 Tecolote Research, Inc

Correlation's "place" in Cost Model Development

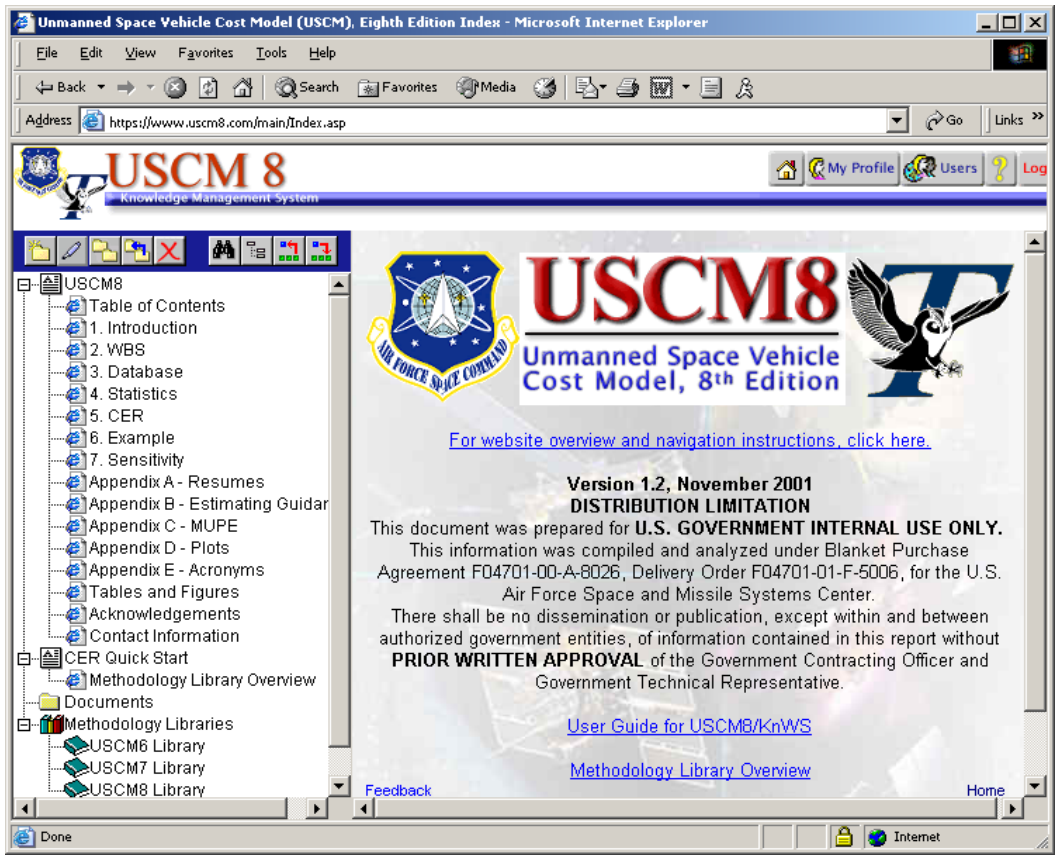


© 2003 Tecolote Research, Inc

A “realistic” cost model

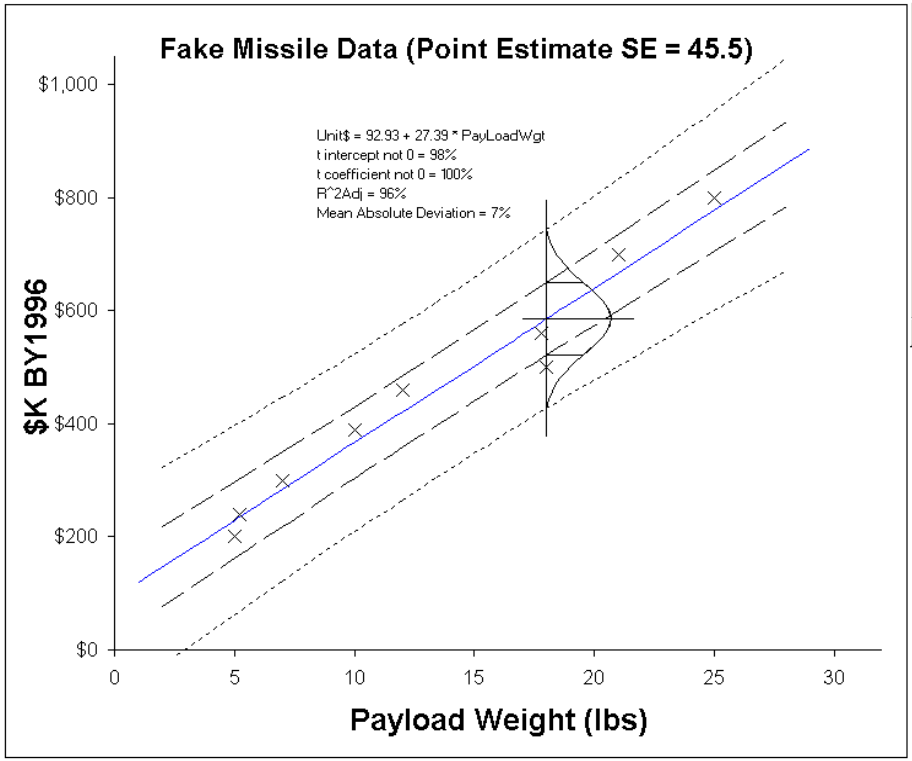
- Space System NR
  - Program Management/Systems Engineering
  - Payload (P/L) Non Recurring
    - Payload IA&T
      - Integration, Assembly, Test and Checkou
      - Software Integration
    - Payload PME NR
      - Optical Telescope Assembly (OTA)
      - Pointing Subsystem
      - Focal Plane Assembly (FPA)
      - Signal Processing Assembly (SPA)
      - PL Software
      - Thermal Control Subsystem (TCS)
  - Spacecraft (S/C) Non Recurring
    - Integration, assembly, Test and Checkout (IA
      - Spacecraft IA&T
      - Software Integration
    - Spacecraft PME NR
      - Structures & Mechanisms
      - Thermal Control Subsystem (TCS)
      - Electrical Power Subsystem (EPS)
      - Attitude Determination & Control System (
      - Spacecraft Software
      - TT&C Subsystem
      - Communications Subsystem (CS)
      - Propulsion Subsystem (PS)

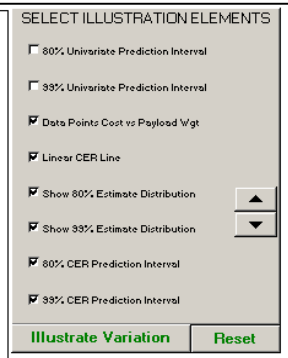
- Non-Recurring Cost of a Space System
- CERs from the Unmanned Space Vehicle Cost Model (USCM)
  https://www.uscm8.com/Default.asp



© 2003 Tecolote Research, Inc

Accuracy of a CER





Standard Error of the Estimate = 42.2 = $\sqrt{\frac{\sum(y-\hat{y})^2}{n-k}}$

y = Data Point
ŷ = Predicted Point
n = Number of DataPoints
k = Number of Coefficien ts

The further your point estimate is from the centroid of the sample data, the greater the error.

Unit$ = 92.93 + 27.39 * Wgt
R^2Adj = 96%
Mean Absolute Deviation = 7%

	Lower Bound of Data	Mid Range of Data	Upper Bound of Data
Input Weight (lbs)	4	15	23
Confidence Level (%)	80%	80%	80%
Point Estimate Standard Error	**48.5**	**44.6**	**48.6**
Lower Bound	$134	$441	$654
Estimate	$202	$504	$723
Upper Bound	$271	$567	$792
	Bounds For RI$K		
Lower Bound	66%	87%	90%
Upper Bound	134%	113%	110%

TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

© 2003 Tecolote Research, Inc

Statistically Derived Prediction Intervals

$$Adj.\,SE = SE * \sqrt{1 + \frac{1}{n} + \frac{\left(\frac{x_0 - \bar{x}}{S_x}\right)^2}{n}} = SE * \sqrt{1 + \frac{1}{n} + \frac{\left(\frac{distance}{sample\ std}\right)^2}{n}}$$

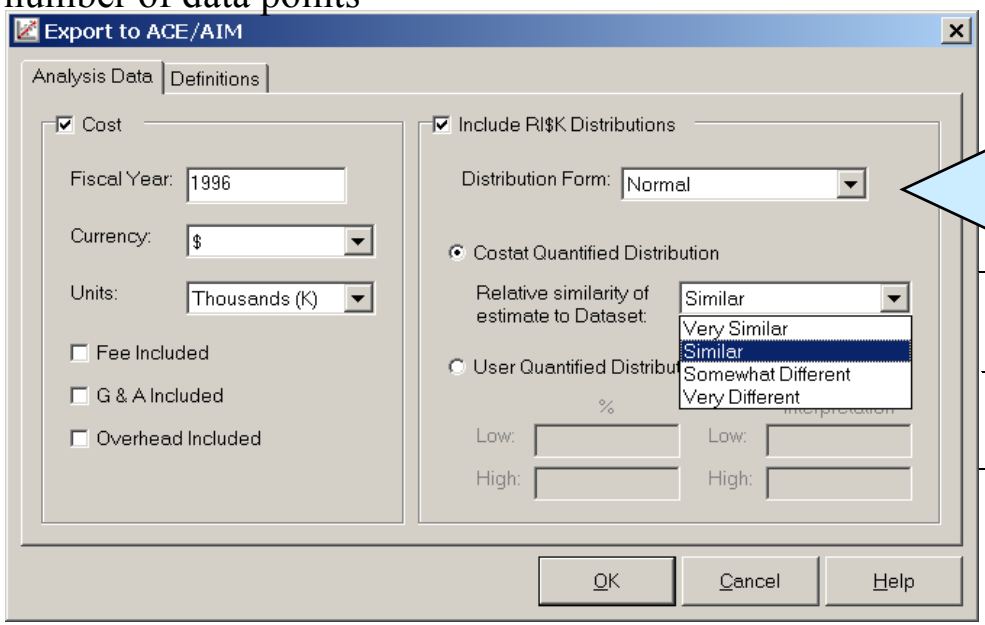
where:

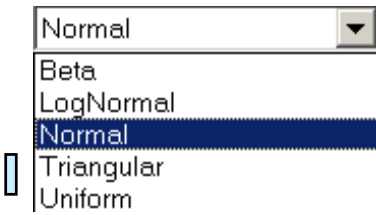
x_0 = the value of the independent variable used in the estimate

$\bar{x}$ = the mean of the independent variable in database

S_x = uncorrected sample standard deviation of the independent variable

n = the number of data points



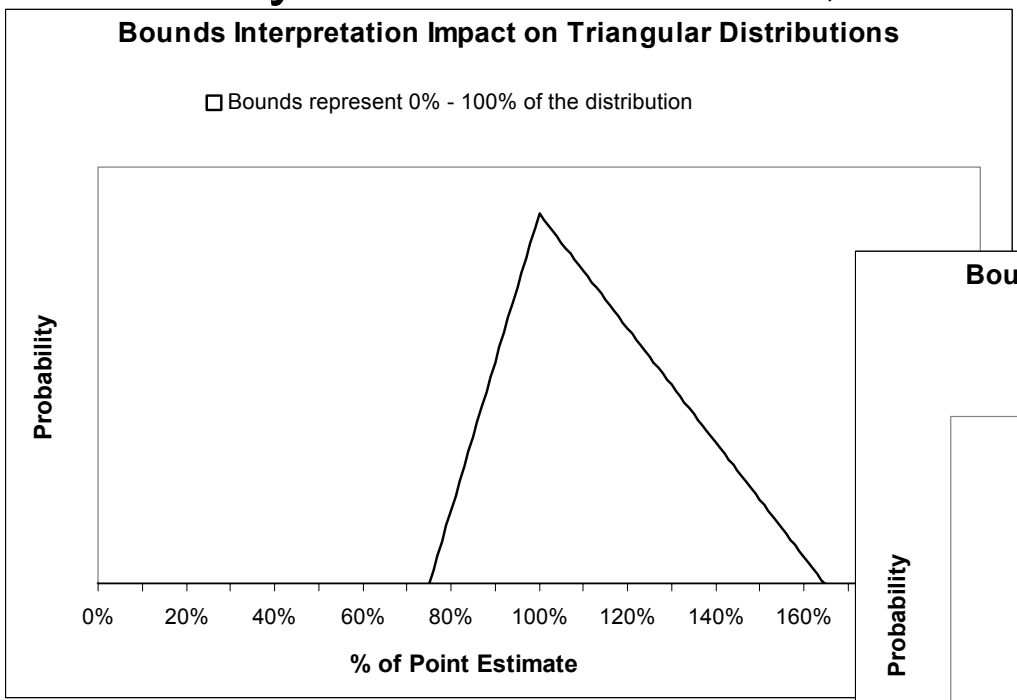


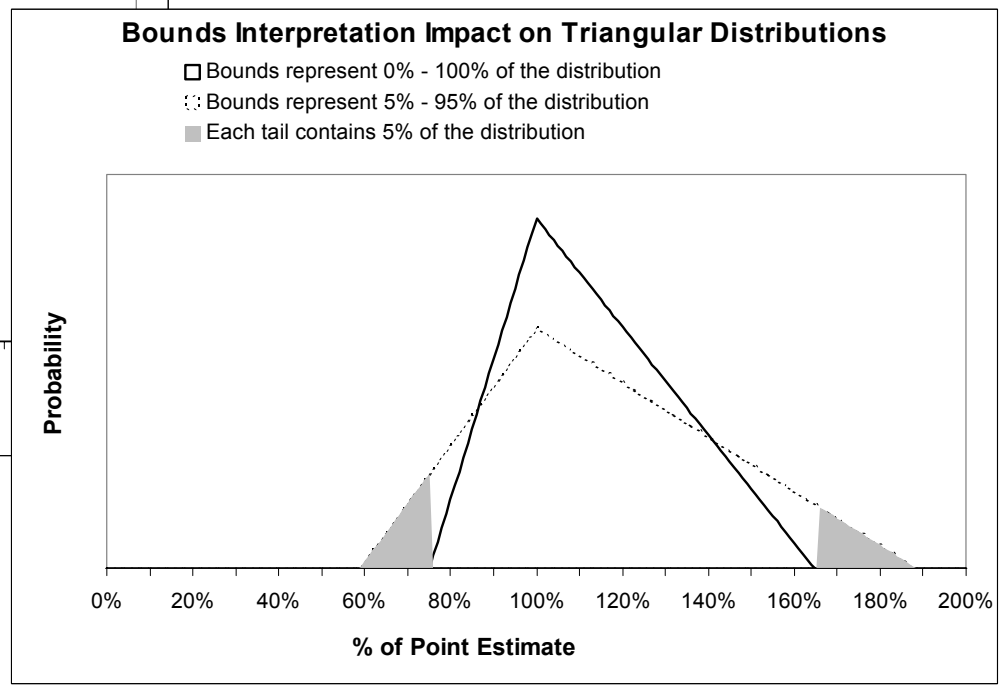
$$\frac{distance}{samplestd} \begin{cases} 0.25 & \text{Very Similar} \\ 0.75 & \text{Similar} \\ 1.50 & \text{Different} \\ 3.00 & \text{Very Different} \end{cases}$$

© 2003 Tecolote Research, Inc

Choosing Risk Distributions, Bounds and Penalty Factors

See "Specification of Risk Distributions for Cost Risk Analysis" Peter Frederic, ISPA/SCEA June 2003





Selection of shape and bounds is not sufficient. Need to define the <u>bounds meaning</u> as well.

© 2003 Tecolote Research, Inc

Theoretical Basis for the ACE Correlation Method

- Pearson's Product Moment Correlation v.s. Spearman's Rank Order Correlation
- ACE uses the Pearson's definition to model correlations in risk simulations.

- Lurie-Goldberg's Simulation Method[1] is summarized in the paper.
- ACE uses a modified Lurie-Goldberg algorithm to create a set of variables that match the user-supplied correlations.

1. Simulating Correlated Random Variables; Philip M. Lurie and Matthew S. Goldberg; Institute for Defense Analyses; 32nd ORCAS; 2-5 February 1989

© 2003 Tecolote Research, Inc

Differences between ACE and Lurie-Goldberg

- ACE only allows the user to enter a single vector of correlation coefficients where the correlations are relative to the dominant cost driver in a particular "Group" of WBS elements. By doing this, the remaining members of the correlation matrix are "implied" (and therefore consistent) and the algorithm is simplified.

- ACE uses ranks during the simulation process to smooth out the resulting variables to make them suitable for the Latin-Hypercube (LH) simulation. Ranking in this context is for the purpose of generating the LH draws such that they closely resemble the original input distributions, and it should not be confused with rank order correlation.

- ACE does not iterate on the user supplied "Group Strengths" to achieve the desired correlations among the WBS elements. Nonetheless, in our test cases the user-defined group strengths match the desired correlations very closely, all within 0.5%.

© 2003 Tecolote Research, Inc

General Steps for the ACE/RI$K Algorithm

- Generate n independent draws, Z1, Z2, …Zn, from a standard normal distribution.
- Construct n correlated standard normal random variables X1, X2, … Xn using Cholesky's pairwise factorization formula.

$$X_1 = Z_1$$

$$X_2 = \rho_2 Z_1 + \sqrt{1-\rho_2^2}\, Z_2$$

$$X_3 = \rho_3 Z_1 + \sqrt{1-\rho_3^2}\, Z_3$$

$$\ldots$$

$$X_n = \rho_n Z_1 + \sqrt{1-\rho_n^2}\, Z_n$$

- Generate the corresponding uniform LH draws for the Xi variables consistent with the value of the normal cumulative probability for each of the Xi values.
- Invert the uniform draws by the user-defined marginal distribution Fi:

$$Y_i = F_i^{-1}(U_i)$$

© 2003 Tecolote Research, Inc

A Study of Correlated Risk Distributions using ACE

- The algorithm in ACE is simple, there is no need to iterate, marginal distributions are preserved, and the desired correlations are achieved. Our tests do not reveal significant differences in results if you go to the trouble of defining a complete, even inconsistent, correlation matrix.
- The impact of correlation on risk results was studied using the model described earlier and a systematic layering of risk assumptions.

	Cost Method Risk			Configuration Risk		
Case Name	**Risk on All CERs**	**Correlation on Selected CER Risk**	**Low Correlation on all other CERs**	**Risk on All Inputs**	**Correlation on Selected Input Risk**	**Low Correlation on all other Inputs**
NoRiskOnWBSRiskOnInputs				X		
NoRiskOnWBSCorOnInputs				X	X	
NoRiskOnWBSCorOnInputs+Low				X	X	X
RiskOnWBSNoRiskOnInputs	X					
RiskOnWBSRiskOnInputs	X			X		
RiskOnWBSCorOnInputs	X			X	X	
CorOnWBSNoRiskOnInputs	X	X				
CorOnWBSRiskOnInputs	X	X		X		
CorOnWBSCorOnInputs	X	X		X	X	
CorOnWBSCorOnInputs+LowWBS	X	X	X	X	X	
CorOnWBSCorOnInputs+LowAllElse	X	X	X	X	X	X

© 2003 Tecolote Research, Inc

Assigning Correlation to Selected Elements

ACE - [51b3cCorOnWBSCorOnInputsSpaceSys.acw - RI$K (BY2003 $K)]

File Edit Workscreen Input Calc Reports Tools Window Help

RI$K

Telescope structure wgt

	WBS/CES Description	Unique ID	Equation / Throughput	BASELINE	Distribution Form	Low or Low %	High or High %	Grouping	Group Strength
32	Gimbal			17341.8*					
33	Gimbal Structure		70.215 * GIMBALSTRWT^0.830	2966.0*	LogNormal	50%	150%	GimbalWBS	.3
34	Motor Drive Electronics			812.8*	Triangular	90%	150%	GimbalWBS	.5
35	LOS Computer		256.878*LOSCOMPTUDEWT	7089.8*	Triangular	80%	150%	GimbalWBS	D
36	IMU electronics		256.878*IMUPMATUDEWT	6473.3*	Triangular	80%	150%	GimbalWBS	.9
78	*PAYLOAD VARIABLES								
82	Gimbal structure weight	GIMBALSTRWT	73	73.0*	Triangular	70%	130%	GimballInput	.3
83	Gimbl Drive motor weight	MOTORDRVPCDWT	11	11.0*	Triangular	70%	130%	GimballInput	.5
84	Los Computer weight	LOSCOMPTUDEWT	23	23.0*	Triangular	70%	130%	GimballInput	D
85	IMU weight	IMUPMATUDEWT	21	21.0*	Triangular	70%	130%	GimballInput	.9

Ready

Correlations Input Into ACE

Gimbal				
Gimbal Structure	100%	15%	30%	27%
Motor Drive Electronics		100%	50%	45%
LOS Computer			D	90%
IMU electronics			90%	100%

Correlation of Motor Drive to IMU is assumed to be 0.5*0.9=0.45

- "LOS Computer" selected as "dominate". Pairwise **correlation** established. ACE "fills in" the remainder of the correlation matrix.

© 2003 Tecolote Research, Inc

SSCAG Risk Subgroup

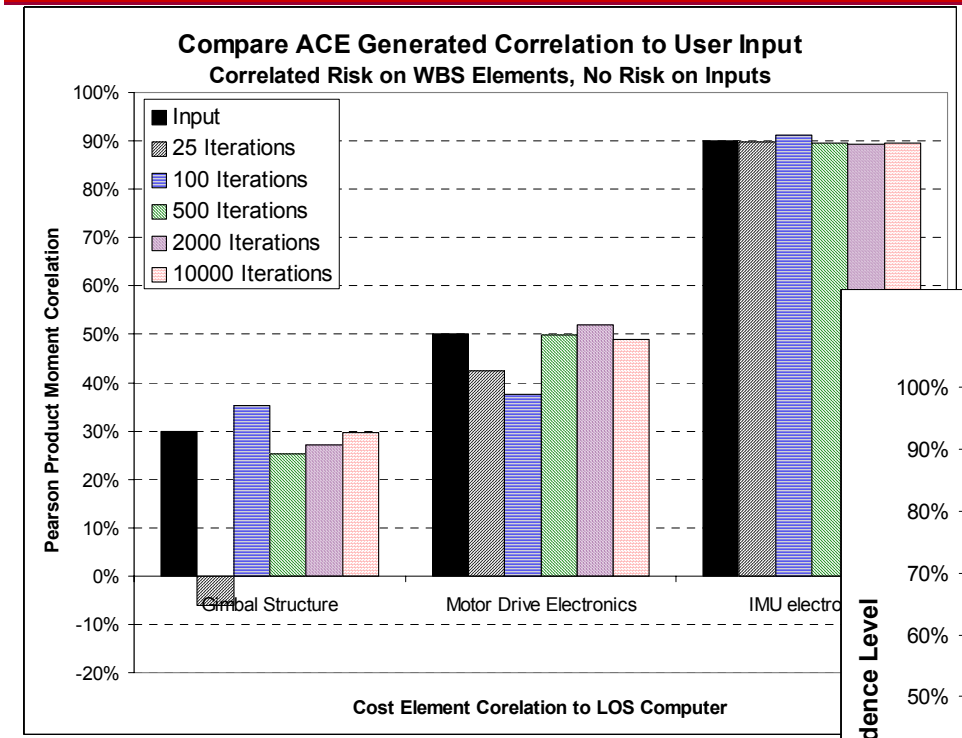
ACE Correlation Utility

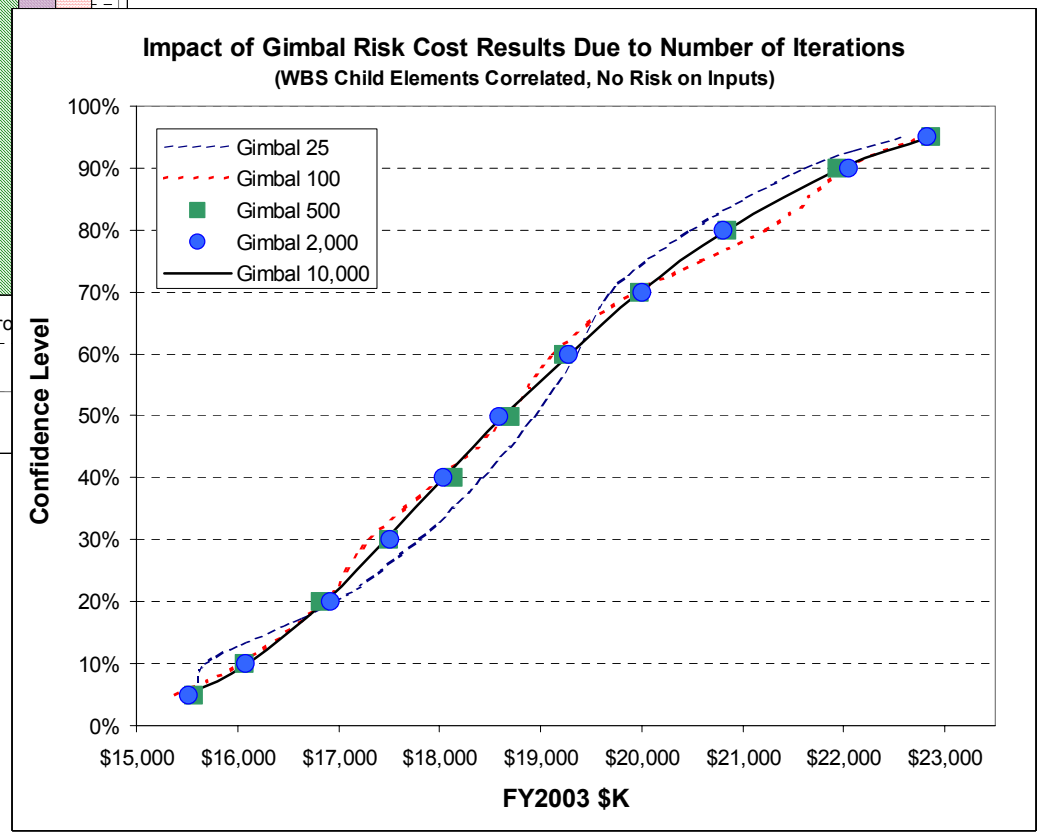
To measure the correlation achieved in the ACE risk simulation, we created a utility in Excel (available upon request) to capture results for each iteration of the risk simulation on user selected rows of the cost model.

The Excel function "CORREL" is used to calculate the Pearson Correlation coefficient between selected elements in the estimate and build the associated full correlation matrix

© 2003 Tecolote Research, Inc

RI$K Iterations Required

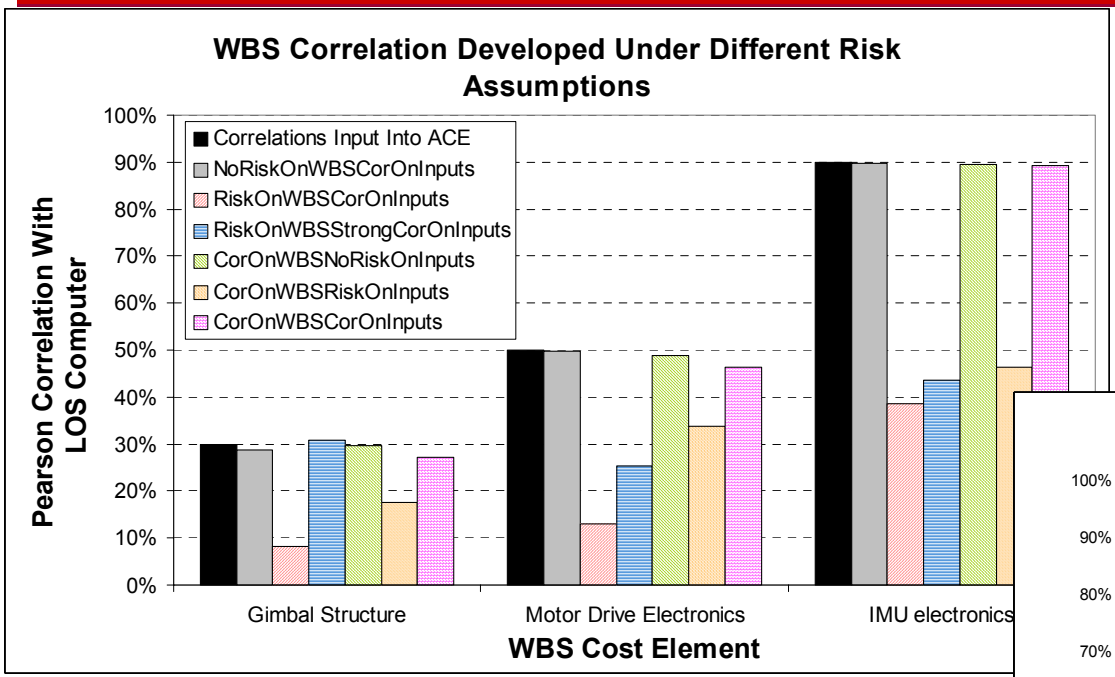


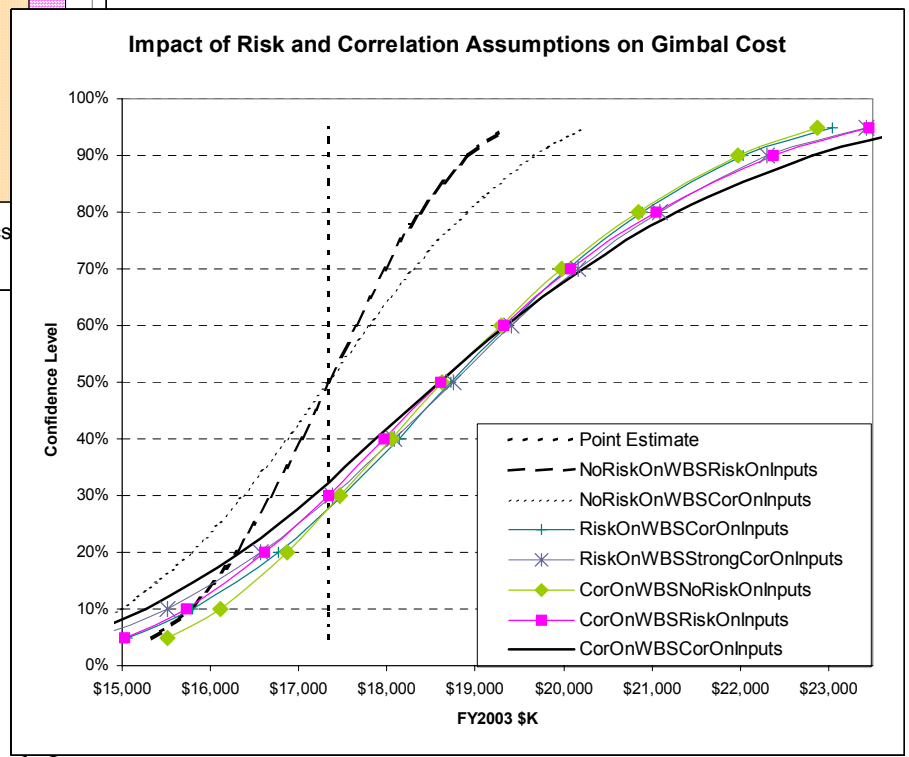


TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

© 2003 Tecolote Research, Inc

Impact on Gimbal Cost by Layering Risk Assumptions



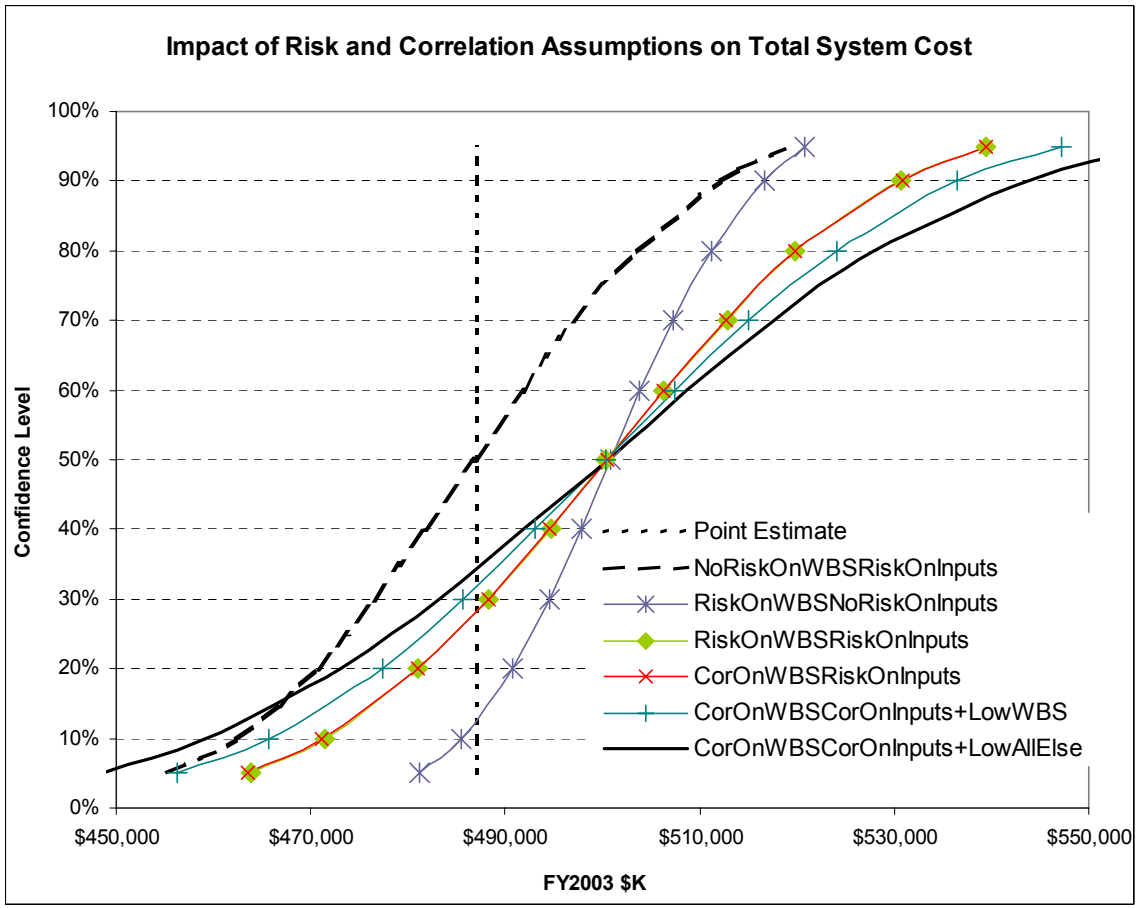


TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

© 2003 Tecolote Research, Inc

SSCAG Risk Subgroup

Impact on on Total Cost by Layering Risk Assumptions



In this model, "most" of the risk is modeled by uncorrelated risk to both inputs and WBS cost elements.

Adding correlation changes the cost result at the 80% confidence level only 1% and 2% at the 90% confidence level.

New after the presentation.

While the cost model was reasonably realistic, the risk assumptions were not consistent with the CERs, nor were they intended to be since the focus was on the impact of correlation on a more general set of risk assumptions.

However the audience was very familiar with this kind of cost estimate and it was noted that the CoV of the final result was only 7% (the audience expected closer to 30%). I undertook to rerun the analysis based on more realistic risk assumptions.

TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

© 2003 Tecolote Research, Inc

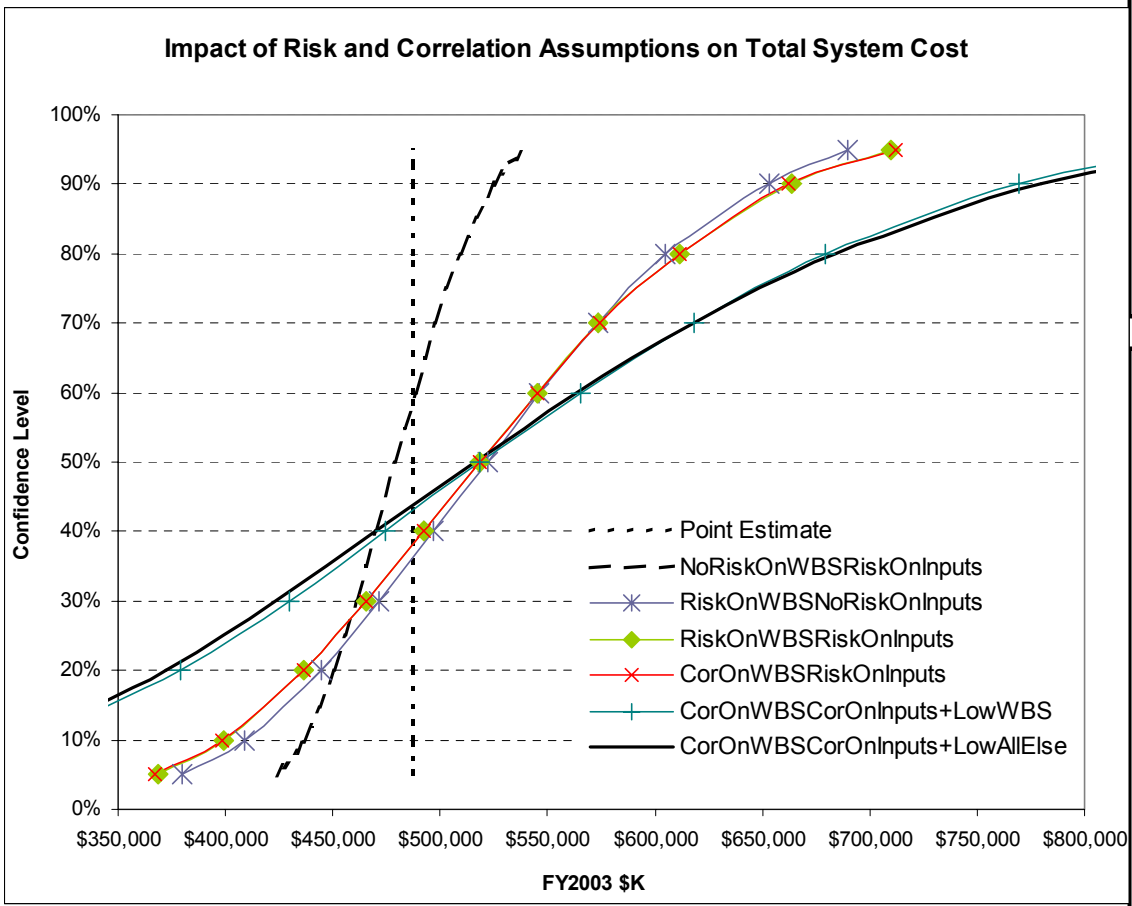
Risk Assumption Changes

(New after the presentation)

- In the original model, log-normal distributions were applied to power form equations. This is consistent with CERs generated by OLS in log space (linear in log space). If the CERs were generated using MUPE instead (as these were), symmetric normal distributions are appropriate as an initial assumption.
- In the original model, bounds were assigned more or less at random consistent with many general models. These bounds were replaced with bounds consistent with USCM CERs.
- The biggest change was the interpretation assumption. In the original model the low/high bounds were assumed to be 0/100%. This is not unreasonable for triangular or uniform distributions. However, it has a dramatic effect on normal and log-normal distributions (makes them unreasonably narrow). Simply changing this assumption to 10/90 doubled the CoV of the final result to 14%.
- In the original model, Gimbal elements were explicitly correlated while all other elements were pairwise correlated 30% to a dominant element. This results in cross correlations of 9%. To cause all cross correlations to be uniformly 20%, 45% was applied to all “other” elements without specifying a dominant element. This results in the cross correlation of 45%^2 (20%) across all elements. In ACE, if you specify a dominant element, you may enter pairwise correlations. If you want a uniform correlation applied across all elements, enter the square root of the desired correlation and do not set a dominant element.

© 2003 Tecolote Research, Inc

Impact on on Total Cost by Layering "New" Risk Assumptions



In this model, the impact of correlating the Gimbal elements is insignificant. Applying 20% across all remaining WBS elements and inputs increases the cost result at 80% by 12%. The CoV of the final result is 35%.

As in the previous example, applying risk to the CERs and inputs in ACE, before layering correlation, captures most of the risk. Forcing a 20% correlation across all elements (other than the Gimbal) does have a significant impact in this model.

Although the CoV of the final result is 35%, it might be excessive. To force even a 20% correlation across all elements is contrary to correlation studies on some datasets.

© 2003 Tecolote Research, Inc

Concluding Remarks

- ACE uses the Pearson's definition to model correlations and uses a modified Lurie-Goldberg algorithm to establish correlation during the risk simulation process.
- The ACE Correlation Utility will allow the analyst to measure the correlations achieved in the ACE RI$K simulation.
- In this model, 500 to 2000 iterations were sufficient for ACE to establish the user defined correlation and produce stable results.
- Correlations applied at the WBS level will be affected if risk is then applied at the input level.
- Cost correlation is not the same as "CER error correlation." In other words, strong correlations between cost elements in a database should not be mistaken as evidence that residuals or percentage errors of our estimating methodologies derived from the same database are correlated.
- If correlations are found in a database, the analyst should not overlook the possibility that these apparent cost correlations may in fact be due to cost driver correlations.
- Relative value across cost elements, distribution form/dispersion selections, number of correlated elements, and model functional relationships will influence the impact of applying correlation.
- The user must experiment to determine if it is worth spending resources investigating correlation in deference to other sources of cost model uncertainty.

© 2003 Tecolote Research, Inc

TECOLOTE RESEARCH, INC.

Bridging Engineering and Economics

Since 1973

Backup Slides

SSCAG Risk Subgroup

Setting Shape, Bounds, Iterations and other Defaults in ACE RI$K

ACE - [51b2aRiskOnWBSNoRiskOnInputsSpaceSys.acw - RI$K (BY2003 $K)]

File Edit Workscreen Input Calc Reports Tools Window Help

RI$K

Triangular

	WBS/CES Description	Unique ID	Equation / Throughput	BASELINE	Distribution Form	Low or Low %	High or High %	Low Interpretation	High Interpretation
20	Space System NR			487178.7*					
21	Program Management/Systems Er	PMSE$	1.487*(PLNR+SCNR)^0.841	79943.0*	LogNormal	90%	115%		
22	Payload (P/L) Non Recurring	PLNR		127136.1*					
23	Payload IA&T			19028.2*					
24	Integration, Assembly, Test anc		850.764 + 0.159 * PLPME	18210.1*	Triangular	80%	130%		
25	Software Integration		.28*PLSW	818.2*	Normal	80%	120%		
26	Payload PME NR	PLPME		108107.8*					
27	Optical Telescope Assembly ((			9650.3*					
28	Structure		70.215 * OTASTRWT^0.830	6302.0*	LogNormal	50%	150%		
29	Electrical		256.664*OTAELECTR^0.761	3348.2*	Triangular	90%	200%		
30	Pointing Subsystem			23206.0*					
31	Scan Mirror		70.215 * SCANMIRRORSTRWT^0.830	1137.2*	LogNormal	50%	150%		
32	Gimbal			17341.8*					
33	Gimbal Structure		70.215 * GIMBALSTRWT^0.830	2966.0*	LogNormal	50%	150%		
34	Motor Drive Electronics		416.033+23.754*MOTORDRVPCDWT	812.8*	Triangular	90%	150%		
35	LOS Computer		256.878*LOSCOMPTUDEWT	7089.8*	Triangular	80%	150%		
36	IMU electronics		256.878*IMUPMATUDEWT	6473.3*	Triangular	80%	150%		
78	*PAYLOAD VARIABLES								
79	Telescope structure wgt	OTASTRWT	181	181.0*					
80	Telescope electrical components we	OTAELECTR	23	23.0*					
81	Scann Mirror weight	SCANMIRRORSTRWT	23	23.0*					
82	Gimbal structure weight	GIMBALSTRWT	73	73.0*					
83	Gimbl Drive motor weight	MOTORDRVPCDWT	11	11.0*					
84	Los Computer weight	LOSCOMPTUDEWT	23	23.0*					
85	IMU weight	IMUPMATUDEWT	21	21.0*					

Beta - Beta
LogNormal - Log Norm
None - None
Normal - Normal
Triangular - Triangula
Uniform - Uniform
Weibull - Weibull

Ready

ACE Session Options

General | Calculation | Errors | Inflation | RI$K | Editor

Solution Method: Latin Hypercube

Number of Iterations: 10000

Interpretation
Low: 0 %
High: 100 %

RI$K Output

Level	Value
1	0.50
2	15.00
3	20.00
4	25.00
5	99.50

Sunk Years
Last Year: 2002

Allocation
This is an experimental heuristic process that causes confidence level results to sum, please see help.

Allocate at 70 % confidence

Allocation markers defined in: <Level 2 WBS Elements>

Note: Allocation options are only used when allocation is selected in a report (Phased, Budgetary, or Cost Category).

OK Cancel Default... Help

TECOLOTE RESEARCH, INC.
Bridging Engineering and Economics
Since 1973

© 2003 Tecolote Research, Inc

Pearson's Product Moment Correlation

$$r = \frac{\sum (X - \bar{X})(Y - \bar{Y})}{\sqrt{\sum (X - \bar{X})^2}\sqrt{\sum (Y - \bar{Y})^2}}$$

or

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{\left(n\sum X^2 - \left(\sum X\right)^2\right) * \left(n\sum Y^2 - \left(\sum Y\right)^2\right)}}$$

n = number of ordered pairs
σ = standard deviation
μ = mean
X = first variable of an ordered pair
Y = second variable of an ordered pair

© 2003 Tecolote Research, Inc

Perfect Correlation with PMP

Microsoft Excel - ACE SCEA Case Study Correlation Utility Beta1a.xls

File Edit View Insert Format Tools Data Window Help Acrobat

Favorites Go CloseFile SetSheets LoadHR

F4 = =CORREL('Result from Each Iteration'!B3:B2003,'Result from Each Iteration'!D3:D2003)

Clear Sheet

	A	B						
1			ACE Session Row Number →	13	14	18	20	24
2			Marker Name →	PMP	PMP	PMP	PMP	PMP
3	ACE Session Row Number:	Marker Name:	WBS:	Prime Mission Product	System Engineering & Program Management	Data and Technical Orders	Initial Spares	System Training
4	13	PMP	Prime Mission Product	100.00%	100.00%	100.00%	100.00%	100.00%
5	14	PMP	System Engineering & Program Management		100.00%	100.00%	100.00%	100.00%
6	18	PMP	Data and Technical Orders			100.00%	100.00%	100.00%
7	20	PMP	Initial Spares				100.00%	100.00%
8	24	PMP	System Training					100.00%

Configuration and Help | Result from Each Iteration | Corre

Ready

© 2003 Tecolote Research, Inc