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Cost Risk Analysis
"Standards"

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13 April 2005

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Objective

- **Describe a systematic simulation based cost risk analysis approach demonstrating how to model:**
  - CER risk (including factor relationships)
  - Configuration (cost driver) risk
  - Correlation (Pearson product moment, not Spearman rank order)
- **Propose standards to characterize and present the results**
- **Propose what needs to be "published" to bring standardization to Cost Risk analysis independent of the tool(s) selected**
- **Compare Crystal Ball, @Risk, ACE and FRisk to an analytically solved case study and case studies for which no analytical solution is feasible.**

Previously presented to SCEA, AIAA, AFCAA, NAVSEA, USMC, NAVAIR , NASA CSG

Outline

- Setting the Stage: Overview of Existing Guidance
- Proposing a Process: A Six Step Cost Risk Analysis "Standard" Approach
  - Show how the NASA 12 Tenets are captured
  - Focus on modeling cost risk, configuration risk and correlation
  - Identify key decisions required to establish a standard approach
- Available Risk Simulation Tools:
  - Crystal Ball, @Risk, and ACE RI$K all give the same results for the same problem (including correlation application).
  - How to ensure fair comparison across tools
- Concluding Observations

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Setting the Stage

Cost Risk Analysis Publications

- Risk Management Policies from DoD 5000.4-M Cost Analysis Guidance and Procedures
  http://acc.dau.mil/simplify/ev.php?ID=6388_201&ID2=DO_TOPIC
- Department of the Army Cost Analysis Manual May 2002
  http://www.ceac.army.mil/ce/default.asp
- (Air Force) Cost Analysis Guidance And Procedures 1 October 1997
  http://www.saffm.hq.af.mil/afcaa/
- NASA Cost Estimating Handbook 2002
  http://www.jsc.nasa.gov/bu2/NCEH/
  http://www.jsc.nasa.gov/bu2/conferences/NCAS2004/index.htm
- FAA Life Cycle Cost Estimating Handbook v2 03 Jun 2002
  http://www.faa.gov/asd/ia-or/lccehb.htm
- Parametric Estimating Initiative (PEI) Parametric Estimating Handbook Spring 1999
  http://www.ispa-cost.org/PEIWeb/newbook.htm
- Recent new AFCAA study by RAND. “Towards a Cost Risk Analysis Policy”

General Guidance that is Tough to Implement

- “Areas of cost estimating uncertainty will be identified and quantified.”
- “Areas of uncertainty, such as pending negotiations, concurrency, schedule risk, performance requirements that are not yet firm, appropriateness of analogous systems, level of knowledge about support concepts, critical assumptions, etc., *should* be presented.”
- “Uncertainty will be quantified by the use of probability distributions or ranges of cost.”
- “Detailed back-up material will be provided.”
- “Experts disagree on the sources of uncertainty in systems acquisition.”

Sources of Cost Estimating Uncertainty

- **Uncertainty *commonly attempted* in cost risk models:**
  - Cost estimating relationship (CER) risk
  - Cost factors such as labor rates, labor rate burdens, etc
  - Configuration risk (variation in the technical descriptions driving the CERs)
  - Schedule and technical risk (in excess of that captured in the CER)
  - Correlation between risk distributions

- **Uncertainty *commonly missing* in cost risk models:**
  - Potential for massive and frequent requirements changes
  - Budget Perturbations, Congressional actions
  - Re-work, and re-test phenomena
  - Contractual arrangements (contract type, prime/sub relationships, etc)
  - Potential for disaster (labor troubles, shuttle loss, satellite “falls over”, war, etc)
  - Probability that if a discrete event occurs it will invoke a project cost

  - **NOT** the subject of this presentation, even though **NASA Tenet 8** requires it and most DoD organizations want/need to see it captured in the estimate

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NASA Cost Risk Analysis Tenets

1. **subset of cost estimating, supports optimum project management**
2. **common set of risk and uncertainty definitions**
3. **joint activity between subject matter experts and cost analysts**

Presentation Focus

4. **CER risk plus technical risk plus correlation**
5. **combine probabilistic and discrete technical risk assessments**
6. **probability distributions are justifiable, correlation levels based on actual cost history**

7. **cost estimates are “likely-to-be” vice “as specified” for optimum credibility**
8. **account for all known variance sources and include provisions for uncertainty**
9. **cost-risk can be an input to every cost estimate’s Cost Readiness Level (CRL);**
10. **integrates the quantification of cost-risk and schedule risk**
11. **decision makers need to know:**
    - How much money is in the estimate to cover risk events;
    - To which WBS elements are they allocated; and,
    - The confidence level of the estimate;
12. **tons of stuff to be stored in the One NASA Cost Estimating (ONCE) database.**

Index of most recent NASA cost risk papers: http://www.jsc.nasa.gov/bu2/conferences/NCAS2004/index.htm

Description of NASA cost risk tenets: http://www.jsc.nasa.gov/bu2/conferences/NCAS2004/presentations/2

Common Cost Risk Analyst Observations

Analysts want to have…

- **Clear guidance on how to conduct cost risk analysis**
- **Standard expectations for quality and completeness**
- **Consistent approaches for:**
  - Interpreting the point estimate CER (mean?, median? mode?, other?)
  - Sensitivity analysis vs. stochastic analysis?
  - Selecting a distribution and its bounds? Are there defaults?
  - Defining dispersion and/or correlation
  - Adjusting risk for schedule/technical concerns?
  - Planned growth (i.e., weight, power, operational profile, etc margins).
  - Risk allocation
  - How to sum costs with differing confidence levels (think software + hardware)
  - What/how to present to managers (including BY vs. TY)

Analysts want to improve the quality of their risk adjusted cost estimates in a more productive/repeatable way.

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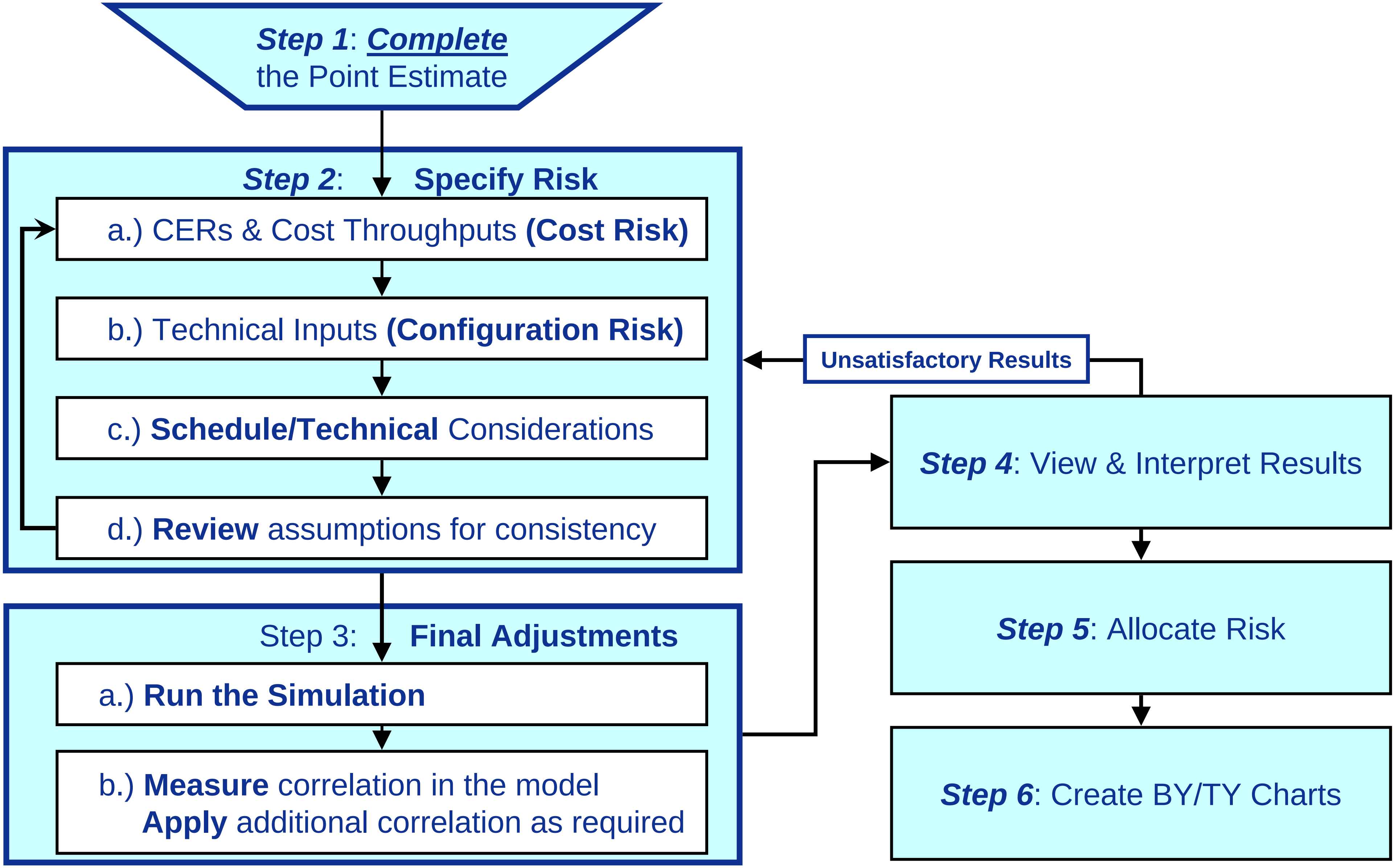
Six Step Cost Risk Analysis Approach

Cost Risk Analysis Approach



Step 1: ***<u>Complete</u>***
the Point Estimate

Step 2: **Specify Risk**

a.) CERs & Cost Throughputs **(Cost Risk)**

b.) Technical Inputs **(Configuration Risk)**

c.) **Schedule/Technical** Considerations

d.) **Review** assumptions for consistency

Step 3: **Final Adjustments**

a.) **Run the Simulation**

b.) **Measure** correlation in the model
Apply additional correlation as required

Unsatisfactory Results

Step 4: View & Interpret Results

Step 5: Allocate Risk

Step 6: Create BY/TY Charts

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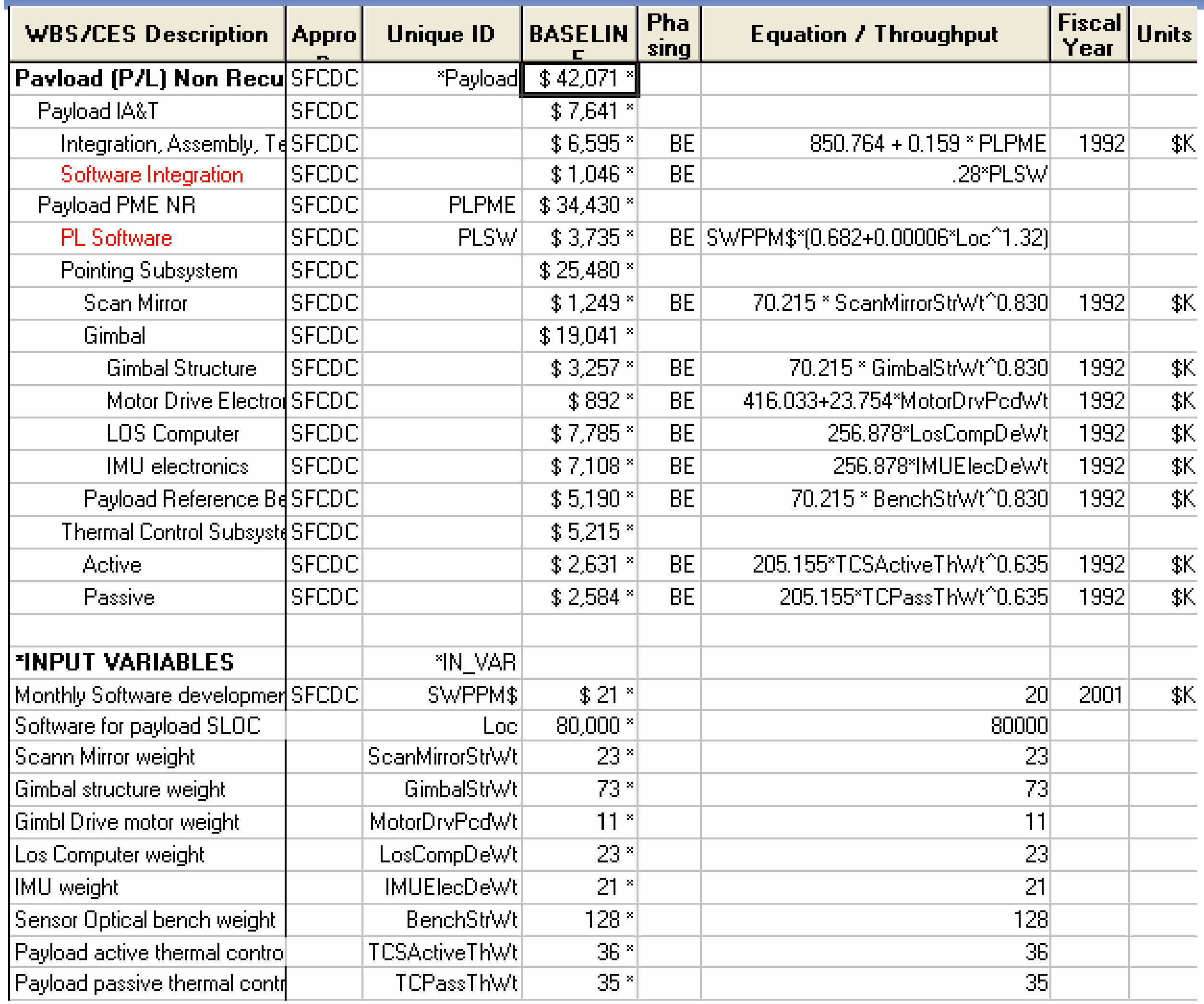
Step 1: The Point Estimate



WBS/CES Description	Appro	Unique ID	BASELIN	Phasing	Equation / Throughput	Fiscal Year	Units
Payload (P/L) Non Recu	SFCDC	*Payload	$ 42,071 *				
Payload IA&T	SFCDC		$ 7,641 *				
Integration, Assembly, Te	SFCDC		$ 6,595 *	BE	850.764 + 0.159 * PLPME	1992	$K
Software Integration	SFCDC		$ 1,046 *	BE	.28*PLSW		
Payload PME NR	SFCDC	PLPME	$ 34,430 *				
PL Software	SFCDC	PLSW	$ 3,735 *	BE	SWPPM$*(0.682+0.00006*Loc^1.32)		
Pointing Subsystem	SFCDC		$ 25,480 *				
Scan Mirror	SFCDC		$ 1,249 *	BE	70.215 * ScanMirrorStrWt^0.830	1992	$K
Gimbal	SFCDC		$ 19,041 *				
Gimbal Structure	SFCDC		$ 3,257 *	BE	70.215 * GimbalStrWt^0.830	1992	$K
Motor Drive Electro	SFCDC		$ 892 *	BE	416.033+23.754*MotorDrvPcdWt	1992	$K
LOS Computer	SFCDC		$ 7,785 *	BE	256.878*LosCompDeWt	1992	$K
IMU electronics	SFCDC		$ 7,108 *	BE	256.878*IMUElecDeWt	1992	$K
Payload Reference Be	SFCDC		$ 5,190 *	BE	70.215 * BenchStrWt^0.830	1992	$K
Thermal Control Subsyste	SFCDC		$ 5,215 *				
Active	SFCDC		$ 2,631 *	BE	205.155*TCSActiveThWt^0.635	1992	$K
Passive	SFCDC		$ 2,584 *	BE	205.155*TCPassThWt^0.635	1992	$K
***INPUT VARIABLES**		*IN_VAR					
Monthly Software developmen	SFCDC	SWPPM$	$ 21 *		20	2001	$K
Software for payload SLOC		Loc	80,000 *		80000		
Scann Mirror weight		ScanMirrorStrWt	23 *		23		
Gimbal structure weight		GimbalStrWt	73 *		73		
Gimbl Drive motor weight		MotorDrvPcdWt	11 *		11		
Los Computer weight		LosCompDeWt	23 *		23		
IMU weight		IMUElecDeWt	21 *		21		
Sensor Optical bench weight		BenchStrWt	128 *		128		
Payload active thermal contro		TCSActiveThWt	36 *		36		
Payload passive thermal contr		TCPassThWt	35 *		35		

Elements of a Point Estimate:

- R&D, Procurement, and O&S
- Software, Hardware & Personnel
- Inherent levels of indenture
- Combination of methods:
    - Engineering build-ups
    - Linear/non-linear CERs
    - Pass-throughs, etc.
- CERs derived from historical data
- CERs (Judgmental)
- Inflation, learning, fee/overhead
- Phased & non-phased variables
- BY & TY phased results

Decision Required: Define what should be addressed in a **risk analysis** (vs. sensitivity analysis). (**NASA Tenet 5**.)

Step 2.a: Cost Estimating Risk: Picking a Distribution Shape and Bounds

Objective Distribution Selection

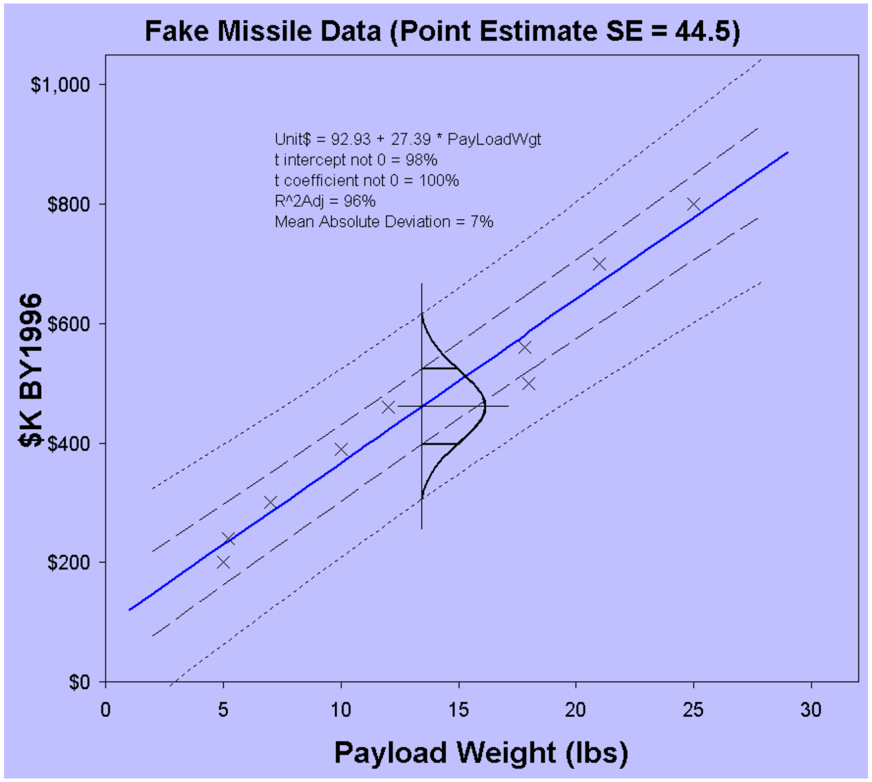
- OLS CERs – produce the “**mean**” (also the mode/median), error is **normally** distributed.
- Log Space OLS CERs - produce the “**median**”, error is **log-normal** in unit space.
- MUPE CERs approximates the “**mean**”, where the error is **normally** distributed.

Subjective Distribution Selection

- Analysts will often declare that risk will be non-symmetrical about the CER result**.**
- Risk on non-parametric CERs (analogy, build-up, through-puts) are almost always subjective.
- Log-normal, weibull, or beta are popular to avoid a sharp peakness around the mode with at least some probability of a large overrun.

Bounds

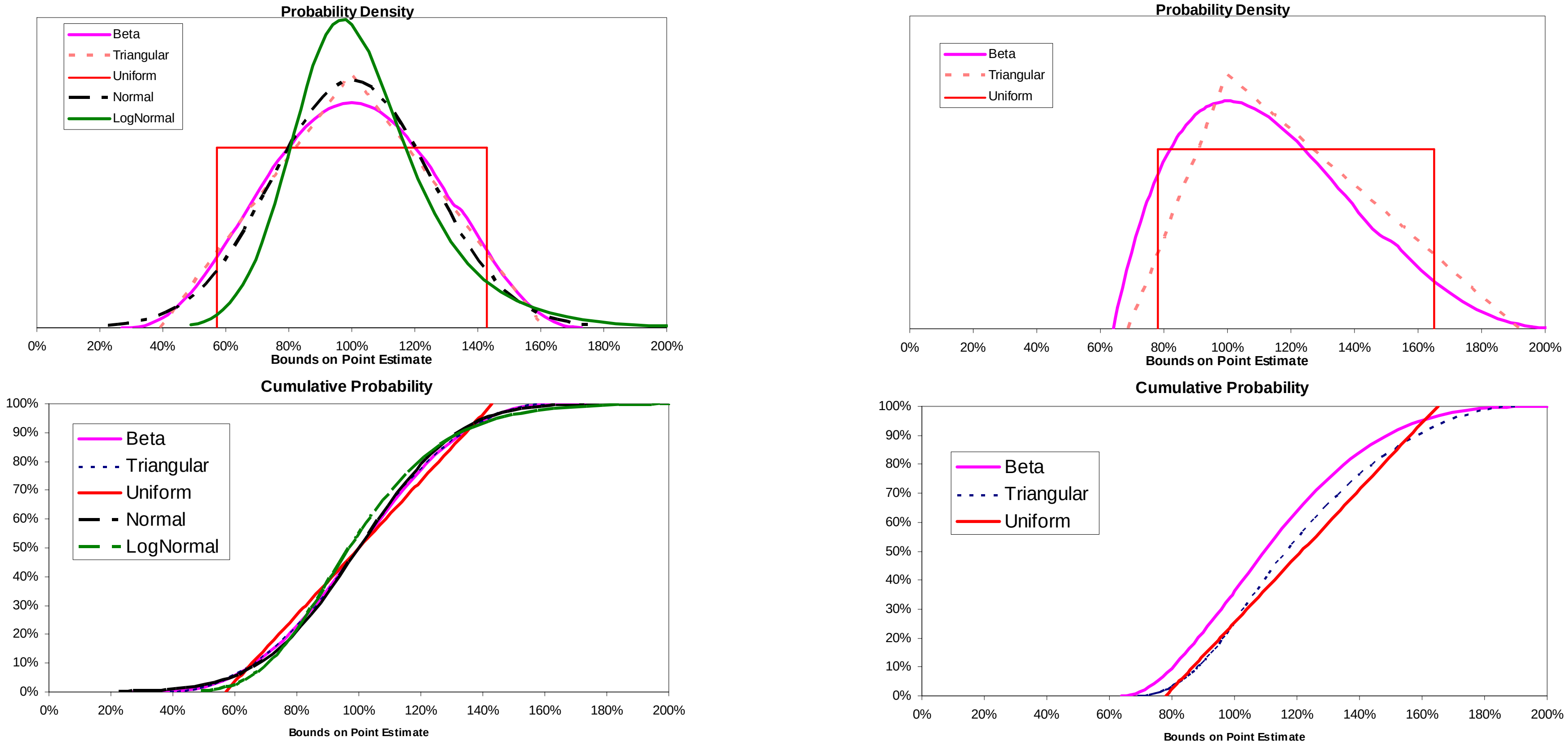
- Statistical analysis (objective)
- Expert Opinion (subjective)



Suggestion (**NASA Tenet 6**)**:**

- Publish the objective distribution shape for each regression technique.
- Define how to interpret the CER (mean or median).
- Provide guidance on what to pick if there is a basis to depart from the objective shapes.

Step 2.a: "Standard" Distribution Shapes and Bounds



- **Plots compare different distribution shapes based on similar dispersion (CoV)**

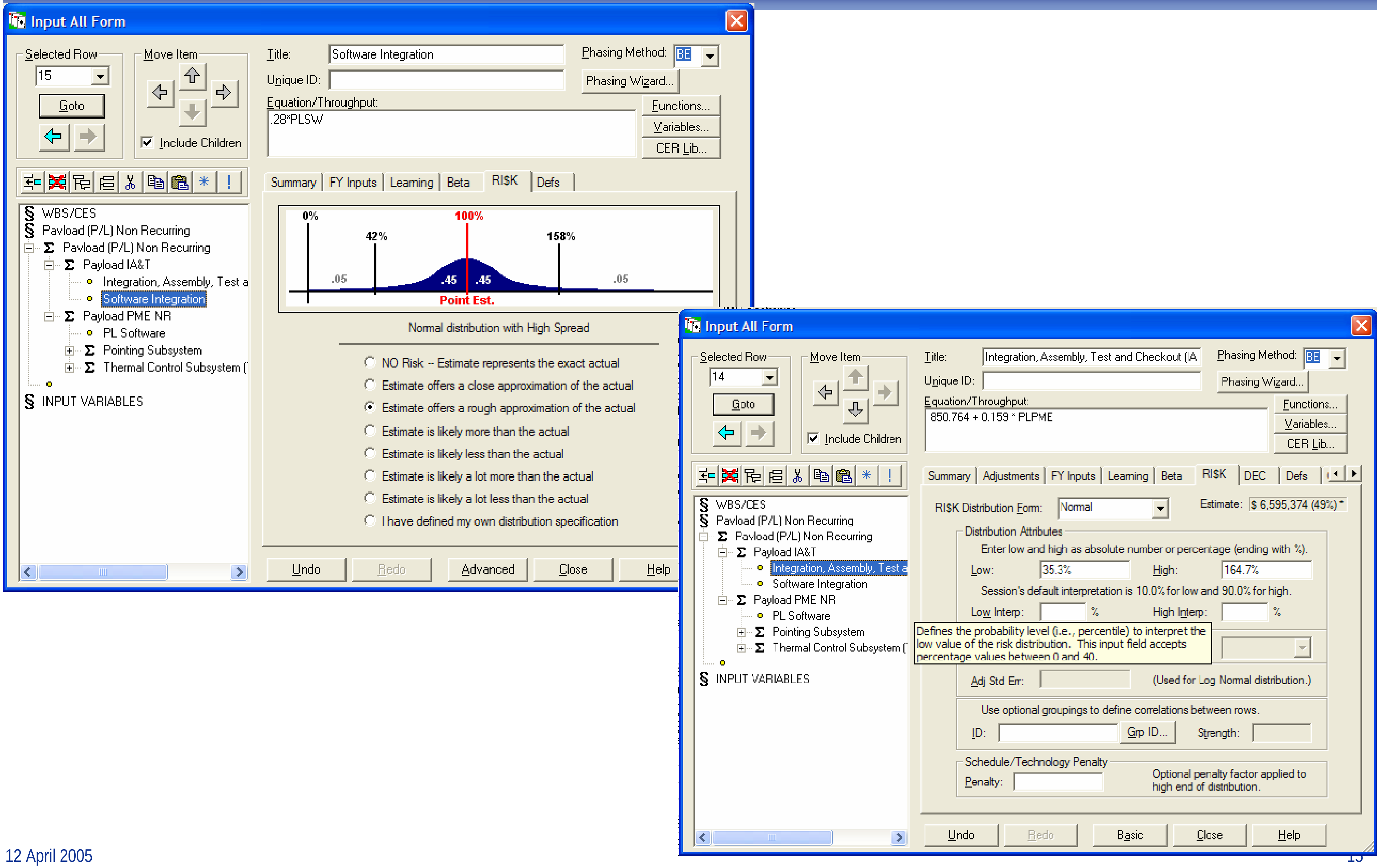
Suggestion:

- Publish "standard" distribution shapes and bounds.
- Develop tables for different distribution shapes by commodity. (**Support for NASA Tenet 6**)

CoV – Coefficient of Variation
= standard deviation/mean

For symmetric distributions:
standard deviation/point estimate

Step 2.a: Use Basic or Advanced Wizards to set Shapes and Bounds



Input All Form

Selected Row: 15

Title: Software Integration

Phasing Method: BE

Equation/Throughput: .28*PLSW

☑ Include Children

Normal distribution with High Spread

- ○ NO Risk -- Estimate represents the exact actual
- ○ Estimate offers a close approximation of the actual
- ● Estimate offers a rough approximation of the actual
- ○ Estimate is likely more than the actual
- ○ Estimate is likely less than the actual
- ○ Estimate is likely a lot more than the actual
- ○ Estimate is likely a lot less than the actual
- ○ I have defined my own distribution specification

Input All Form

Selected Row: 14

Title: Integration, Assembly, Test and Checkout (IA

Phasing Method: BE

Equation/Throughput: 850.764 + 0.159 * PLPME

☑ Include Children

RI$K Distribution Form: Normal

Estimate: $ 6,595,374 (49%) *

Distribution Attributes

Enter low and high as absolute number or percentage (ending with %).

Low: 35.3%

High: 164.7%

Session's default interpretation is 10.0% for low and 90.0% for high.

Low Interp: %

High Interp: %

Defines the probability level (i.e., percentile) to interpret the low value of the risk distribution. This input field accepts percentage values between 0 and 40.

Adj Std Err: (Used for Log Normal distribution.)

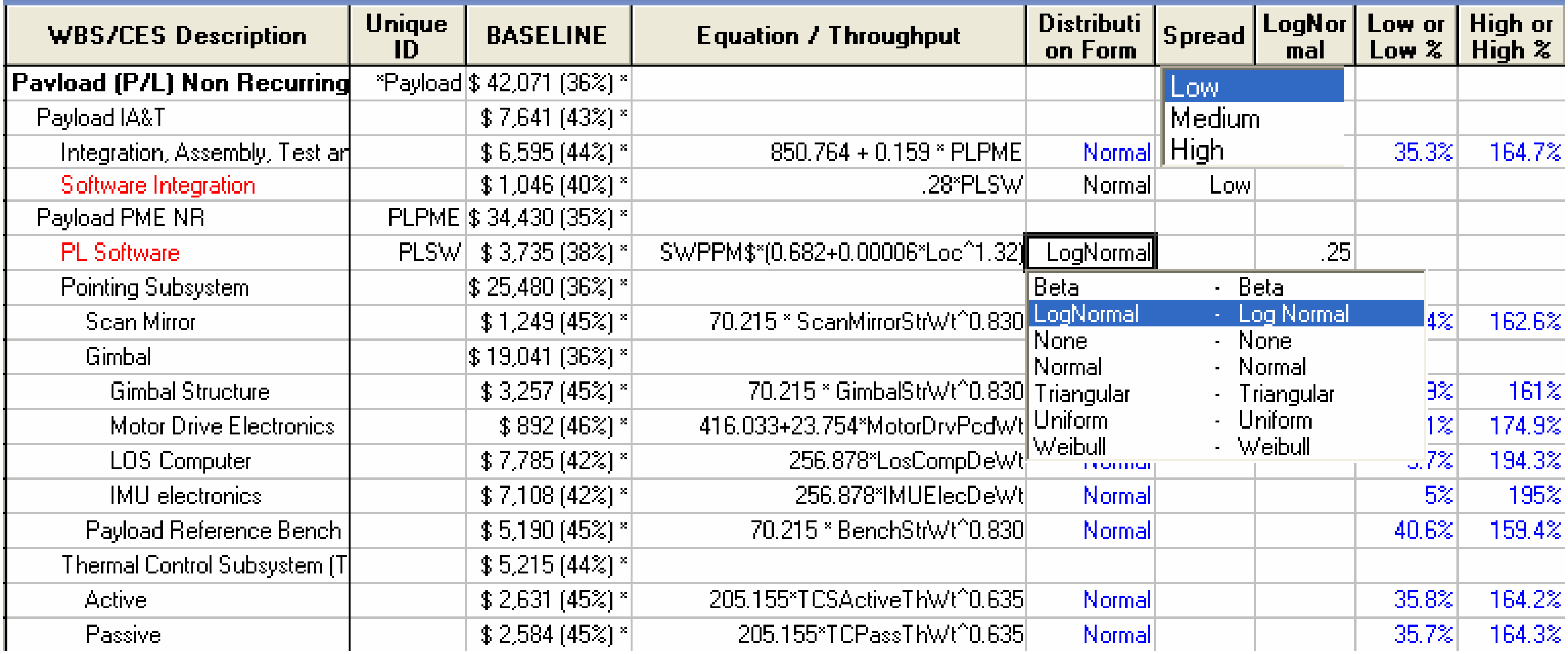
Use optional groupings to define correlations between rows.

ID: Grp ID... Strength:

Schedule/Technology Penalty

Penalty: Optional penalty factor applied to high end of distribution.

Step 2a: Some Potential Display Standards



WBS/CES Description	Unique ID	BASELINE	Equation / Throughput	Distribution Form	Spread	LogNormal	Low or Low %	High or High %
Payload (P/L) Non Recurring	*Payload	$ 42,071 (36%) *						
Payload IA&T		$ 7,641 (43%) *						
Integration, Assembly, Test ar		$ 6,595 (44%) *	850.764 + 0.159 * PLPME	Normal			35.3%	164.7%
Software Integration		$ 1,046 (40%) *	.28*PLSW	Normal	Low			
Payload PME NR	PLPME	$ 34,430 (35%) *						
PL Software	PLSW	$ 3,735 (38%) *	SWPPM$*(0.682+0.00006*Loc^1.32)	LogNormal		.25		
Pointing Subsystem		$ 25,480 (36%) *						
Scan Mirror		$ 1,249 (45%) *	70.215 * ScanMirrorStrWt^0.830				4%	162.6%
Gimbal		$ 19,041 (36%) *						
Gimbal Structure		$ 3,257 (45%) *	70.215 * GimbalStrWt^0.830				9%	161%
Motor Drive Electronics		$ 892 (46%) *	416.033+23.754*MotorDrvPcdWt				1%	174.9%
LOS Computer		$ 7,785 (42%) *	256.878*LosCompDeWt				.7%	194.3%
IMU electronics		$ 7,108 (42%) *	256.878*IMUElecDeWt	Normal			5%	195%
Payload Reference Bench		$ 5,190 (45%) *	70.215 * BenchStrWt^0.830	Normal			40.6%	159.4%
Thermal Control Subsystem (T		$ 5,215 (44%) *						
Active		$ 2,631 (45%) *	205.155*TCSActiveThWt^0.635	Normal			35.8%	164.2%
Passive		$ 2,584 (45%) *	205.155*TCPassThWt^0.635	Normal			35.7%	164.3%

- **Point estimate reflects "median" for lognormal, "mode" for all others.**
- **Right click to choose distribution and "default" spread/skew**
- **Permit dispersion to be specified such that distributions scale with sensitivity analysis….ie bounds that are a % of the point estimate, log SE for log-normal or CoV**
- **Bracketed numbers in Baseline column reports point estimate confidence level**

Step 2.b: Configuration Risk

- **Focus is now on the cost drivers (risk or sensitivity analysis?)**
- **Frequent sources of cost risk: learning slope, lines of code count, weight, composite labor rates, etc. assumptions**
- **Modeling considerations:**
  - Do CER inputs represent design goals or include allowable margin?
  - Do CER inputs represent the mode/mean/median (normal error) or median (log-normal error) or some other percentile value?
  - Are only discrete sets of CER inputs permissible (i.e. is it inappropriate to model them with continuous risk distributions)?
  - Can CER inputs be functionally linked? For instance, can airframe weight be estimated from the engine weight?

Suggestion: NAFCOM permits analysts to assign distributions to the inputs. Publish "default" input variable interpretation, distribution shapes, and bounds based upon commodity type.

Step 2.c: Schedule/Technical Considerations

- **Estimating methods capture some “nominal” schedule/technical cost impact (contributes to regression error term?).**
  - Compare the project you are estimating to the CER source data.
  - Realistically assess the degree to which the schedule and technical considerations compare to the CER source.
- **CERs, estimating methods, analogy and expert opinion estimating processes are influenced by past, real projects.**
- **Difficult to isolate schedule from technical cost impacts. Many approaches assess the impact together.**
- **Subjective assessment.**

Decision Required:

Develop a default method for adjusting risk distributions to capture schedule and technical considerations:

- Parametric approach - penalty factor, additional distribution, etc
- Employ schedule and EVM experts to explicitly model the schedule risk **(NASA Tenet 10).**

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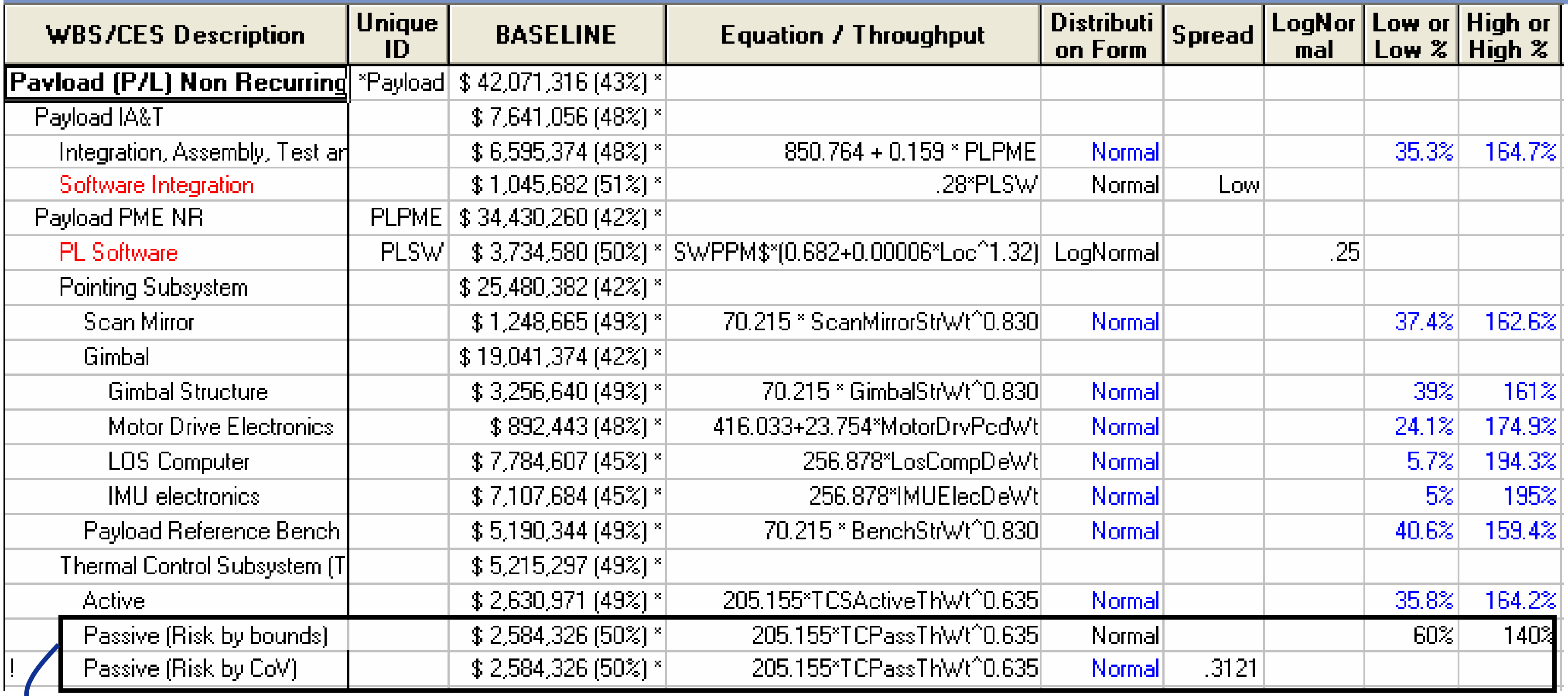
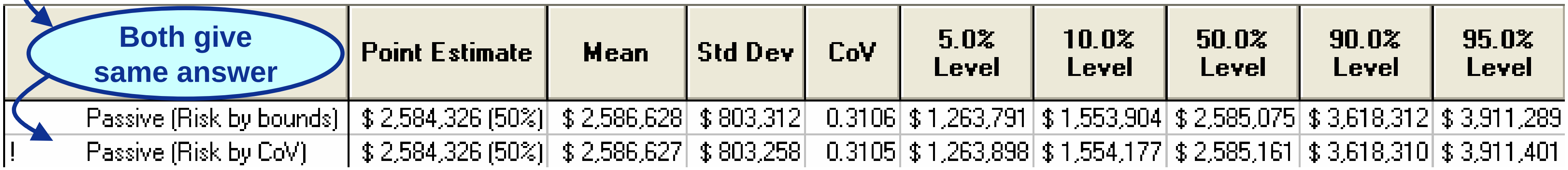
Step 2.d Review for Consistency



WBS/CES Description	Unique ID	BASELINE	Equation / Throughput	Distribution Form	Spread	LogNormal	Low or Low %	High or High %
Payload (P/L) Non Recurring	*Payload	$ 42,071,316 (43%) *						
Payload IA&T		$ 7,641,056 (48%) *						
Integration, Assembly, Test ar		$ 6,595,374 (48%) *	850.764 + 0.159 * PLPME	Normal			35.3%	164.7%
Software Integration		$ 1,045,682 (51%) *	.28*PLSW	Normal	Low			
Payload PME NR	PLPME	$ 34,430,260 (42%) *						
PL Software	PLSW	$ 3,734,580 (50%) *	SWPPM$*(0.682+0.00006*Loc^1.32)	LogNormal		.25		
Pointing Subsystem		$ 25,480,382 (42%) *						
Scan Mirror		$ 1,248,665 (49%) *	70.215 * ScanMirrorStrWt^0.830	Normal			37.4%	162.6%
Gimbal		$ 19,041,374 (42%) *						
Gimbal Structure		$ 3,256,640 (49%) *	70.215 * GimbalStrWt^0.830	Normal			39%	161%
Motor Drive Electronics		$ 892,443 (48%) *	416.033+23.754*MotorDrvPcdWt	Normal			24.1%	174.9%
LOS Computer		$ 7,784,607 (45%) *	256.878*LosCompDeWt	Normal			5.7%	194.3%
IMU electronics		$ 7,107,684 (45%) *	256.878*IMUElecDeWt	Normal			5%	195%
Payload Reference Bench		$ 5,190,344 (49%) *	70.215 * BenchStrWt^0.830	Normal			40.6%	159.4%
Thermal Control Subsystem (T		$ 5,215,297 (49%) *						
Active		$ 2,630,971 (49%) *	205.155*TCSActiveThWt^0.635	Normal			35.8%	164.2%
Passive (Risk by bounds)		$ 2,584,326 (50%) *	205.155*TCPassThWt^0.635	Normal			60%	140%
! Passive (Risk by CoV)		$ 2,584,326 (50%) *	205.155*TCPassThWt^0.635	Normal	.3121			



Both give same answer

	Point Estimate	Mean	Std Dev	CoV	5.0% Level	10.0% Level	50.0% Level	90.0% Level	95.0% Level
Passive (Risk by bounds)	$ 2,584,326 (50%)	$ 2,586,628	$ 803,312	0.3106	$ 1,263,791	$ 1,553,904	$ 2,585,075	$ 3,618,312	$ 3,911,289
! Passive (Risk by CoV)	$ 2,584,326 (50%)	$ 2,586,627	$ 803,258	0.3105	$ 1,263,898	$ 1,554,177	$ 2,585,161	$ 3,618,310	$ 3,911,401

Bounds expressed as % of point estimate **or CoV** (unitless):
- Scale with changes to the point estimate
- Provide a consistent basis for comparison

Step 3a: Run the Simulation

- **Simulation tool results are influenced by:**
  - Interpretation of point estimate
  - Truncation assumption (do you allow cost, weight, etc risk to go negative?)
  - Number of iterations
  - If using Latin Hypercube [LHC], the number of partitions
  - Random seed (impossible to be consistent between tools. Some tools at least provides for consistency across different machines and different versions)

- **When the above assumptions are consistent (as far as possible), Crystal Ball, @Risk, ACE and FRisk all produce similar results.**

Decision Required:

- Identify acceptable risk simulation tools
- Provide guidance on how they should be applied
- Periodically publish “common errors” as new versions are released

Step 3b: Correlation

- **_Measure_ the correlation _already present_ due to modeling relationships to determine if correlation needs to be adjusted**
- **Modeling considerations often overlooked when trying to assess the correlation _already present_ in the cost model**
  - Functional relationships between the input variables
  - Functional relationships between WBS elements
  - More than one CER sharing same risk-adjusted input variable. (example: same risk adjusted learning slope variable driving more than one WBS element)
  - Simulation tool bias (i.e. how random seeds are generated).
- **Input variable functional relationships can be simulated using correlation (i.e.: cause structure weight to “move with” payload weight)**

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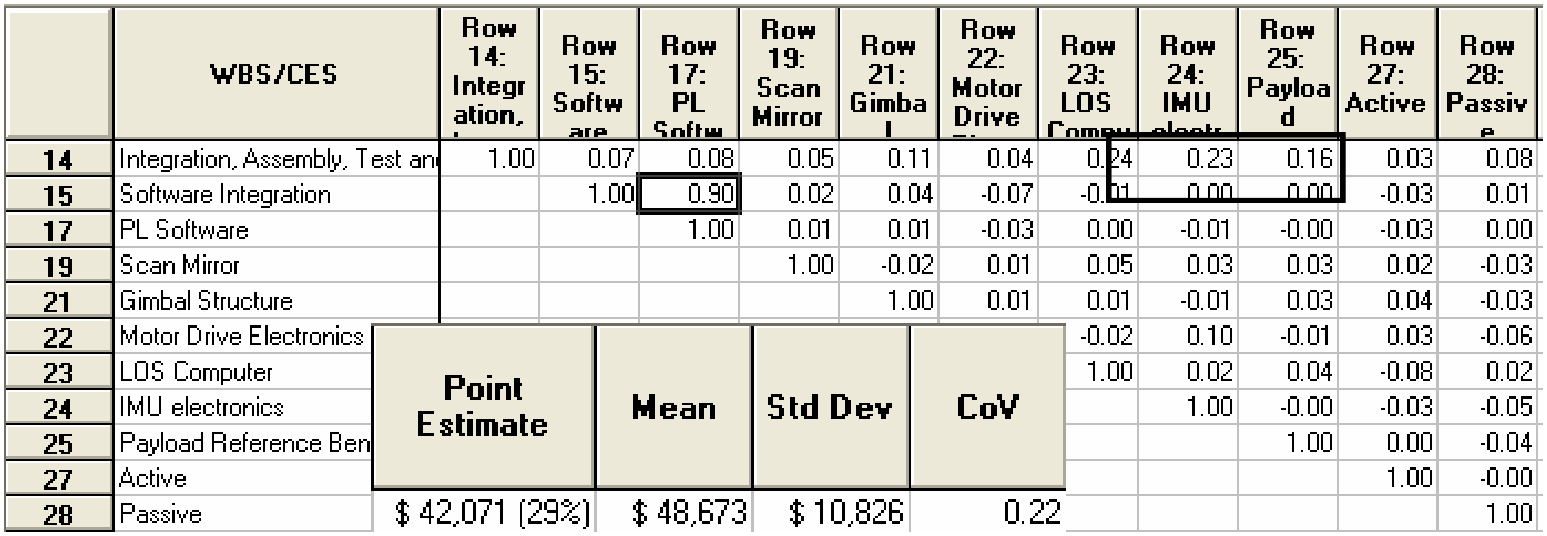
Measure Correlation Present in The Cost Model

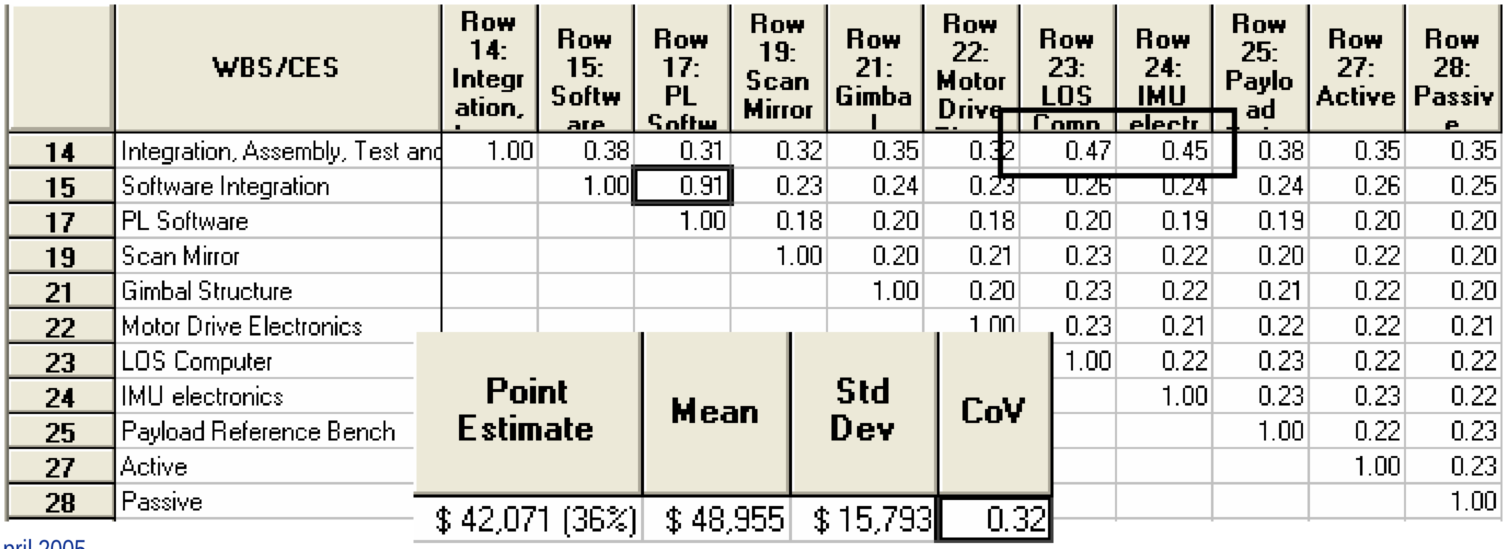


	WBS/CES	Row 14: Integr ation,	Row 15: Softw are	Row 17: PL Softw	Row 19: Scan Mirror	Row 21: Gimba l	Row 22: Motor Drive	Row 23: LOS Compu	Row 24: IMU electr	Row 25: Payloa d	Row 27: Active	Row 28: Passiv e
14	Integration, Assembly, Test an	1.00	0.07	0.08	0.05	0.11	0.04	0.24	0.23	0.16	0.03	0.08
15	Software Integration		1.00	0.90	0.02	0.04	-0.07	-0.01	0.00	0.00	-0.03	0.01
17	PL Software			1.00	0.01	0.01	-0.03	0.00	-0.01	-0.00	-0.03	0.00
19	Scan Mirror				1.00	-0.02	0.01	0.05	0.03	0.03	0.02	-0.03
21	Gimbal Structure					1.00	0.01	0.01	-0.01	0.03	0.04	-0.03
22	Motor Drive Electronics							-0.02	0.10	-0.01	0.03	-0.06
23	LOS Computer							1.00	0.02	0.04	-0.08	0.02
24	IMU electronics								1.00	-0.00	-0.03	-0.05
25	Payload Reference Ben									1.00	0.00	-0.04
27	Active										1.00	-0.00
28	Passive											1.00

Point Estimate	Mean	Std Dev	CoV
$ 42,071 (29%)	$ 48,673	$ 10,826	0.22

Pearson Product moment correlation measured by capturing results from every iteration

(Excel CORREL function can be used to validate)



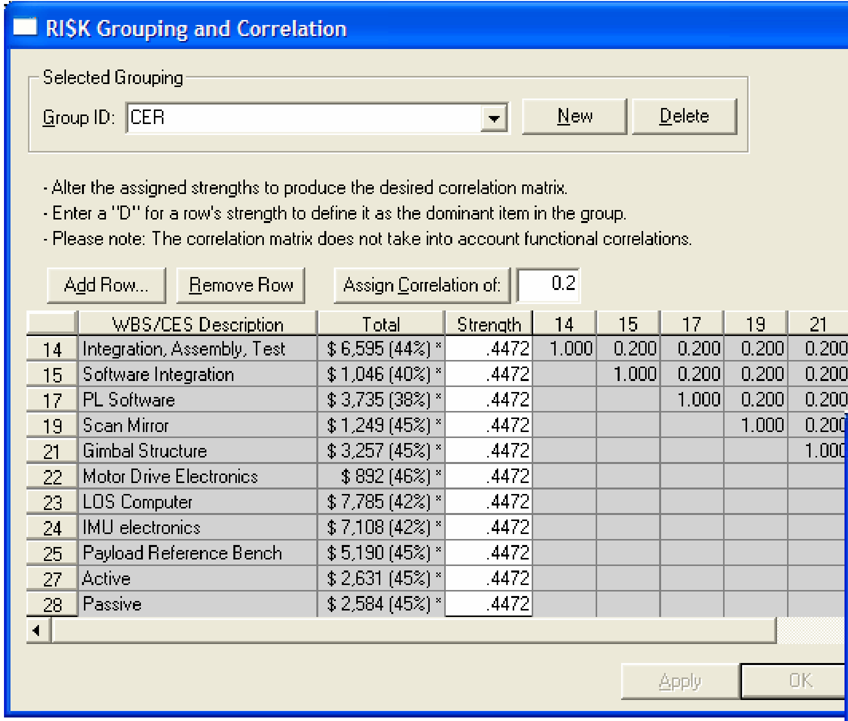
	WBS/CES	Row 14: Integr ation,	Row 15: Softw are	Row 17: PL Softw	Row 19: Scan Mirror	Row 21: Gimba l	Row 22: Motor Drive	Row 23: LOS Comp	Row 24: IMU electr	Row 25: Paylo ad	Row 27: Active	Row 28: Passiv e
14	Integration, Assembly, Test and	1.00	0.38	0.31	0.32	0.35	0.32	0.47	0.45	0.38	0.35	0.35
15	Software Integration		1.00	0.91	0.23	0.24	0.23	0.26	0.24	0.24	0.26	0.25
17	PL Software			1.00	0.18	0.20	0.18	0.20	0.19	0.19	0.20	0.20
19	Scan Mirror				1.00	0.20	0.21	0.23	0.22	0.20	0.22	0.20
21	Gimbal Structure					1.00	0.20	0.23	0.22	0.21	0.22	0.20
22	Motor Drive Electronics						1.00	0.23	0.21	0.22	0.22	0.21
23	LOS Computer							1.00	0.22	0.23	0.22	0.22
24	IMU electronics								1.00	0.23	0.23	0.22
25	Payload Reference Bench									1.00	0.22	0.23
27	Active										1.00	0.23
28	Passive											1.00

Point Estimate	Mean	Std Dev	CoV
$ 42,071 (36%)	$ 48,955	$ 15,793	0.32

Define intention when “injecting” correlation.

Correlation after layering an additional 20% across all elements

Need for Correlation Wizard



RI$K Grouping and Correlation

Selected Grouping

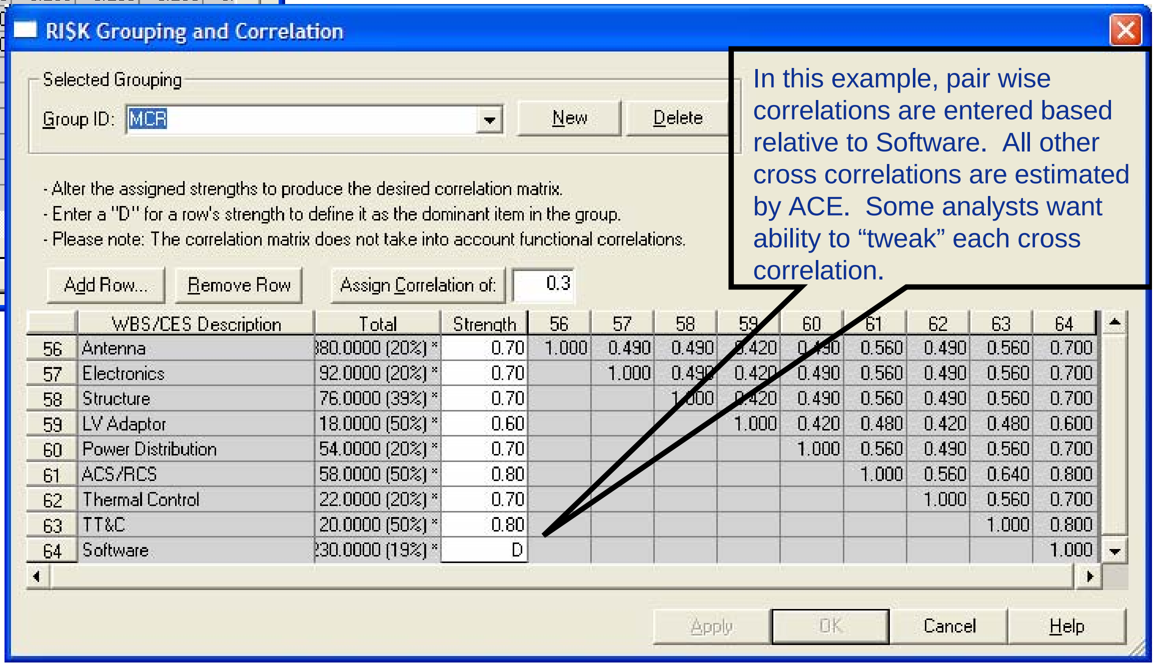
Group ID: CER

- Alter the assigned strengths to produce the desired correlation matrix.
- Enter a "D" for a row's strength to define it as the dominant item in the group.
- Please note: The correlation matrix does not take into account functional correlations.

Assign Correlation of: 0.2

	WBS/CES Description	Total	Strength	14	15	17	19	21	22	23	24	2
14	Integration, Assembly, Test	$ 6,595 (44%) *	.4472	1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.
15	Software Integration	$ 1,046 (40%) *	.4472		1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.
17	PL Software	$ 3,735 (38%) *	.4472			1.000	0.200	0.200	0.200	0.200	0.200	0.
19	Scan Mirror	$ 1,249 (45%) *	.4472				1.000	0.200				
21	Gimbal Structure	$ 3,257 (45%) *	.4472					1.000				
22	Motor Drive Electronics	$ 892 (46%) *	.4472									
23	LOS Computer	$ 7,785 (42%) *	.4472									
24	IMU electronics	$ 7,108 (42%) *	.4472									
25	Payload Reference Bench	$ 5,190 (45%) *	.4472									
27	Active	$ 2,631 (45%) *	.4472									
28	Passive	$ 2,584 (45%) *	.4472									

Ability to layer additional correlation across selected WBS or cost driver elements (or a blend of both)



RI$K Grouping and Correlation

Selected Grouping

Group ID: MCR

- Alter the assigned strengths to produce the desired correlation matrix.
- Enter a "D" for a row's strength to define it as the dominant item in the group.
- Please note: The correlation matrix does not take into account functional correlations.

Assign Correlation of: 0.3

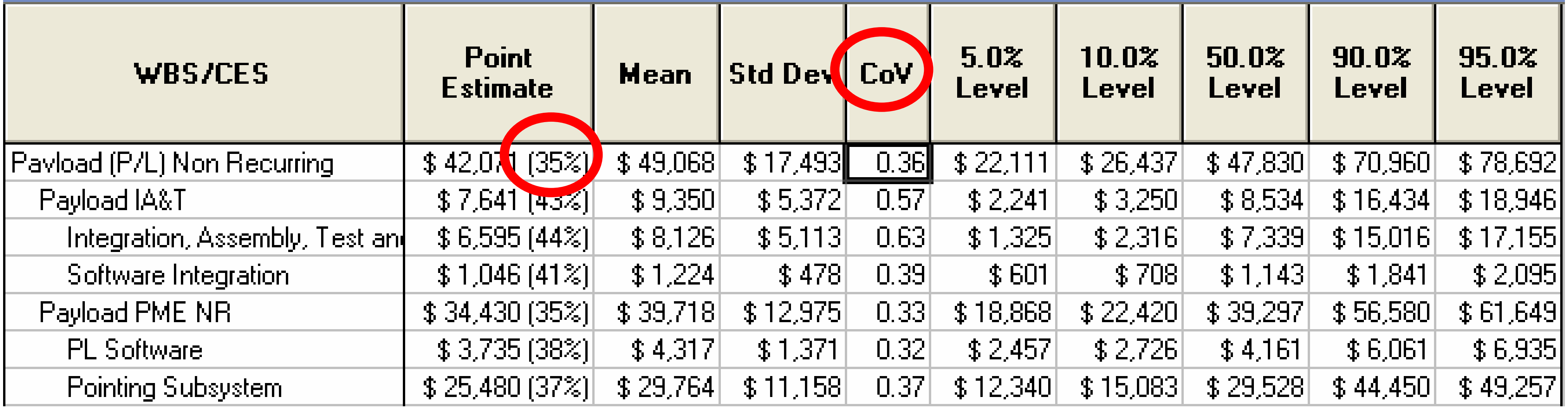
	WBS/CES Description	Total	Strength	56	57	58	59	60	61	62	63	64
56	Antenna	380.0000 (20%) *	0.70	1.000	0.490	0.490	0.420	0.490	0.560	0.490	0.560	0.700
57	Electronics	92.0000 (20%) *	0.70		1.000	0.490	0.420	0.490	0.560	0.490	0.560	0.700
58	Structure	76.0000 (39%) *	0.70			1.000	0.420	0.490	0.560	0.490	0.560	0.700
59	LV Adaptor	18.0000 (50%) *	0.60				1.000	0.420	0.480	0.420	0.480	0.600
60	Power Distribution	54.0000 (20%) *	0.70					1.000	0.560	0.490	0.560	0.700
61	ACS/RCS	58.0000 (50%) *	0.80						1.000	0.560	0.640	0.800
62	Thermal Control	22.0000 (20%) *	0.70							1.000	0.560	0.700
63	TT&C	20.0000 (50%) *	0.80								1.000	0.800
64	Software	230.0000 (19%) *	D									1.000

In this example, pair wise correlations are entered based relative to Software. All other cross correlations are estimated by ACE. Some analysts want ability to "tweak" each cross correlation.

Short cut used by ACE simplifies the entry effort and speeds the simulation. However many would like to have complete control over every element. To date, ACE Government sponsors are not motivated to fund this ability...but are not opposed.

Decisions Required: Define how correlation should be applied. Decide if you should allow the user to **"turn off"** functional correlation.

Step 4: View and Interpret Results



WBS/CES	Point Estimate	Mean	Std Dev	CoV	5.0% Level	10.0% Level	50.0% Level	90.0% Level	95.0% Level
Payload (P/L) Non Recurring	$ 42,071 (35%)	$ 49,068	$ 17,493	0.36	$ 22,111	$ 26,437	$ 47,830	$ 70,960	$ 78,692
Payload IA&T	$ 7,641 (43%)	$ 9,350	$ 5,372	0.57	$ 2,241	$ 3,250	$ 8,534	$ 16,434	$ 18,946
Integration, Assembly, Test an	$ 6,595 (44%)	$ 8,126	$ 5,113	0.63	$ 1,325	$ 2,316	$ 7,339	$ 15,016	$ 17,155
Software Integration	$ 1,046 (41%)	$ 1,224	$ 478	0.39	$ 601	$ 708	$ 1,143	$ 1,841	$ 2,095
Payload PME NR	$ 34,430 (35%)	$ 39,718	$ 12,975	0.33	$ 18,868	$ 22,420	$ 39,297	$ 56,580	$ 61,649
PL Software	$ 3,735 (38%)	$ 4,317	$ 1,371	0.32	$ 2,457	$ 2,726	$ 4,161	$ 6,061	$ 6,935
Pointing Subsystem	$ 25,480 (37%)	$ 29,764	$ 11,158	0.37	$ 12,340	$ 15,083	$ 29,528	$ 44,450	$ 49,257

- **Risk analysis will give context to the point estimate**
- **CoV (Stdev/Mean), confidence of the point estimate (PEcl) and quartile range are useful measures of the overall risk in the cost model (*Tenet 9*).**
- **Observations in DoD Estimates:**
  - Estimates rich in parametric CERs: 15%<CoV<45%, and 5%<PEcl<30%
  - Estimates rich in build-up methods: 5%<CoV<15%, and 30%<PEcl<45%

Suggestion: Identify reasonable, commodity-based metrics the analyst can use to assess the completeness and possibly the quality of the risk analysis as it is being developed. **NASA has done so with the CRL concept.**

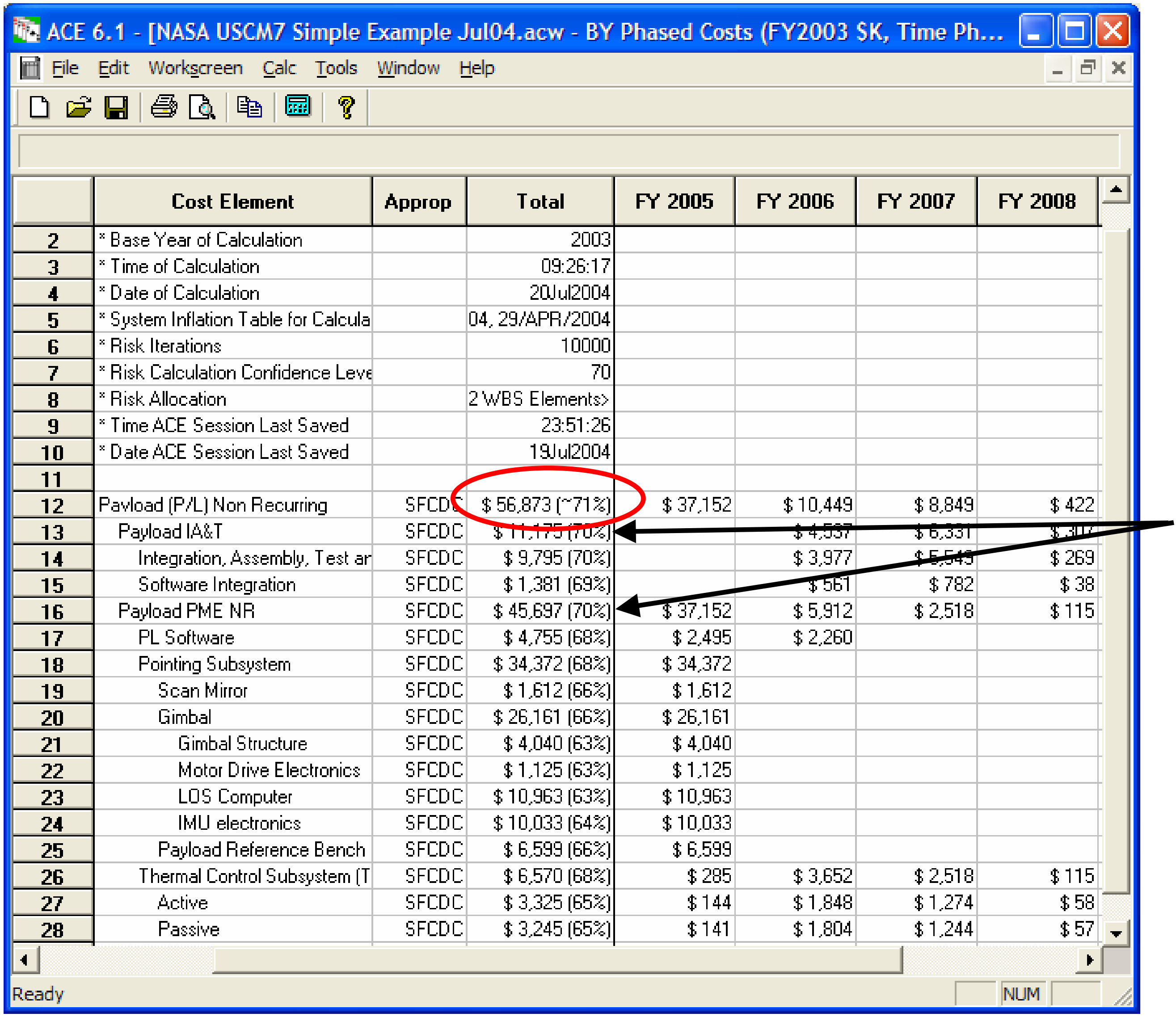
Step 5: Allocate Risk

- **Confidence level results *do not add***
  - Mathematicians are quite happy with this result, budget folks are not.
- **Results must:**
  - Be phased in both BY (constant year) and TY$ (real dollars?)
  - Add up
- **Selection of level from which to allocate risk has a significant impact on total**
- **Many issues must be resolved to define a phased, risk allocation method that yields consistent BY and TY results**
- **Problem is very much exacerbated if policy requires some elements to be at one confidence level (i.e. 80%) and others at another (i.e. 50%)**
- **Phasing assumptions will have <u>*significant impact*</u> on TY risk results.**

Decision Required:

- Choose a “default” risk allocation approach, including how the cost risk dollars should be phased along with acceptable alternatives
- Define how to deal with elements that are at different CLs
- Cost models should be flexible enough to phase the risk dollars consistent with the program managers risk mitigation plans

Consequence of an Allocated Risk Report

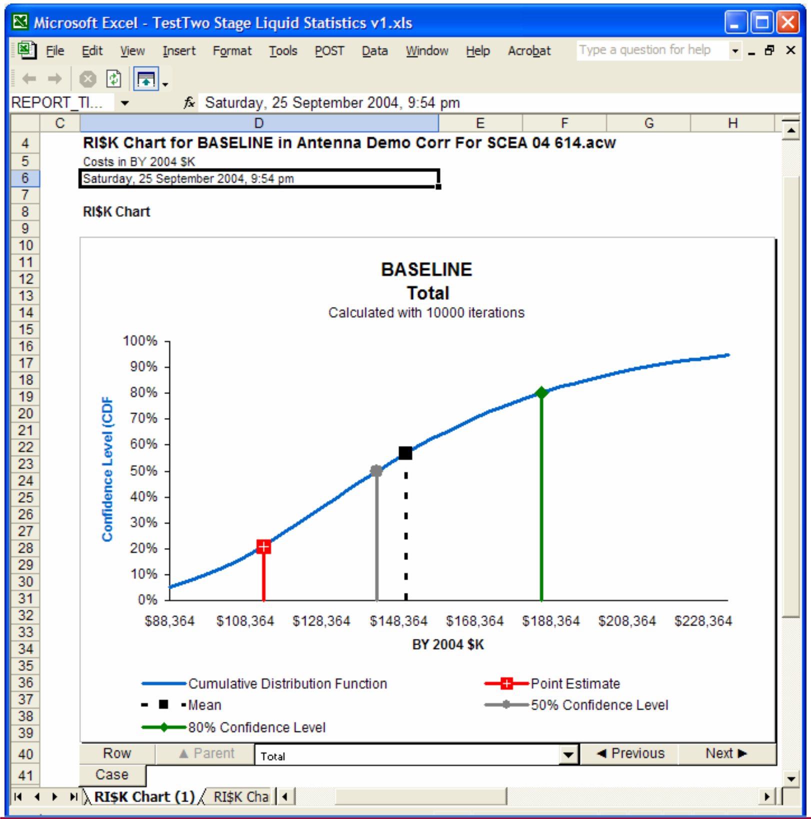


ACE 6.1 - [NASA USCM7 Simple Example Jul04.acw - BY Phased Costs (FY2003 $K, Time Ph...

	Cost Element	Approp	Total	FY 2005	FY 2006	FY 2007	FY 2008
2	* Base Year of Calculation		2003				
3	* Time of Calculation		09:26:17				
4	* Date of Calculation		20Jul2004				
5	* System Inflation Table for Calcula		04, 29/APR/2004				
6	* Risk Iterations		10000				
7	* Risk Calculation Confidence Leve		70				
8	* Risk Allocation		2 WBS Elements>				
9	* Time ACE Session Last Saved		23:51:26				
10	* Date ACE Session Last Saved		19Jul2004				
11							
12	Payload (P/L) Non Recurring	SFCDC	$ 56,873 (~71%)	$ 37,152	$ 10,449	$ 8,849	$ 422
13	Payload IA&T	SFCDC	$ 11,175 (70%)		$ 4,537	$ 6,331	$ 307
14	Integration, Assembly, Test ar	SFCDC	$ 9,795 (70%)		$ 3,977	$ 5,549	$ 269
15	Software Integration	SFCDC	$ 1,381 (69%)		$ 561	$ 782	$ 38
16	Payload PME NR	SFCDC	$ 45,697 (70%)	$ 37,152	$ 5,912	$ 2,518	$ 115
17	PL Software	SFCDC	$ 4,755 (68%)	$ 2,495	$ 2,260		
18	Pointing Subsystem	SFCDC	$ 34,372 (68%)	$ 34,372			
19	Scan Mirror	SFCDC	$ 1,612 (66%)	$ 1,612			
20	Gimbal	SFCDC	$ 26,161 (66%)	$ 26,161			
21	Gimbal Structure	SFCDC	$ 4,040 (63%)	$ 4,040			
22	Motor Drive Electronics	SFCDC	$ 1,125 (63%)	$ 1,125			
23	LOS Computer	SFCDC	$ 10,963 (63%)	$ 10,963			
24	IMU electronics	SFCDC	$ 10,033 (64%)	$ 10,033			
25	Payload Reference Bench	SFCDC	$ 6,599 (66%)	$ 6,599			
26	Thermal Control Subsystem (T	SFCDC	$ 6,570 (68%)	$ 285	$ 3,652	$ 2,518	$ 115
27	Active	SFCDC	$ 3,325 (65%)	$ 144	$ 1,848	$ 1,274	$ 58
28	Passive	SFCDC	$ 3,245 (65%)	$ 141	$ 1,804	$ 1,244	$ 57

- **In this example, risk funds managed from the 2nd level (70%)**
- **Total project dollars required are greater than 70% CL overall**
- **All numbers "add"**

Step 6: Charts and Tables



Saturday, 25 September 2004, 9:54 pm

RI$K Chart for BASELINE in Antenna Demo Corr For SCEA 04 614.acw

Costs in BY 2004 $K

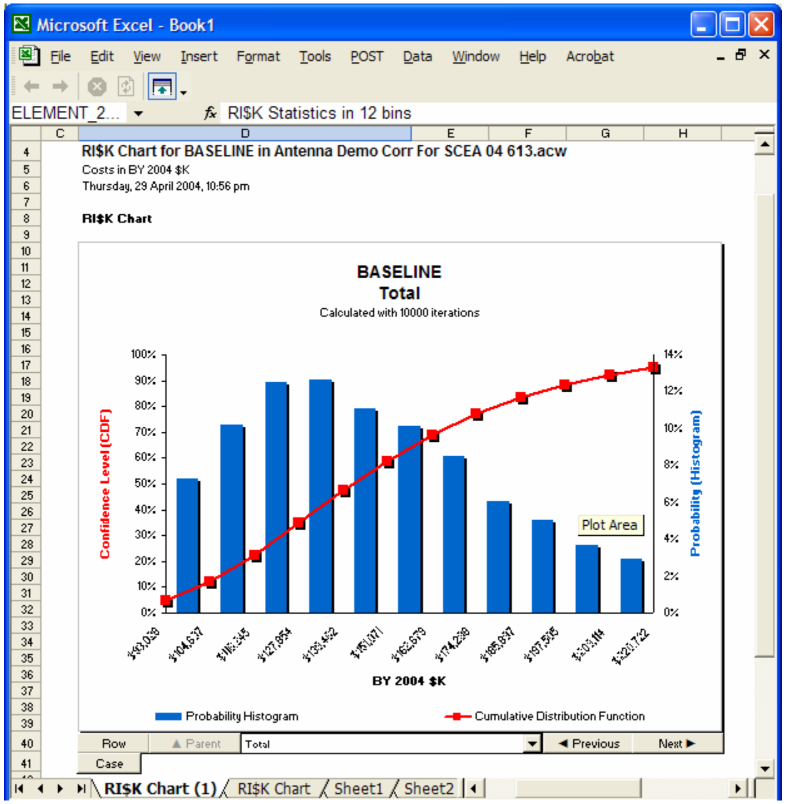
Saturday, 25 September 2004, 9:54 pm

RI$K Chart

BASELINE

Total

Calculated with 10000 iterations



RI$K Statistics in 12 bins

RI$K Chart for BASELINE in Antenna Demo Corr For SCEA 04 613.acw

Costs in BY 2004 $K

Thursday, 29 April 2004, 10:56 pm

RI$K Chart

BASELINE

Total

Calculated with 10000 iterations

Decision Required:

- Identify the standard charts and their contents to be presented to management.
- Ensure consistent x and y-axis arrangements.
- Determine “if” a TY S-curve should be presented and if so, define the process to be used (Sep 04, Army funded such a study and a solution is at hand).

Benefits of Clear Guidance

- **Default positions could establish minimum guidance & expectations for cost risk analysis – not a cookbook**
- **No need to "over specify" the guidance**
- **Advanced analysts will still develop sophisticated models to deal with exceptional circumstances**
- **Establishing a "standard process" will:**
  - Focus analyst's attention on "building" the risk adjusted estimate rather than determining "how" to build it
  - Enable more risk analysis practitioners to "do" cost risk analysis ***with confidence***

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Cost Risk Tools

Compare Cost Risk Tool Results

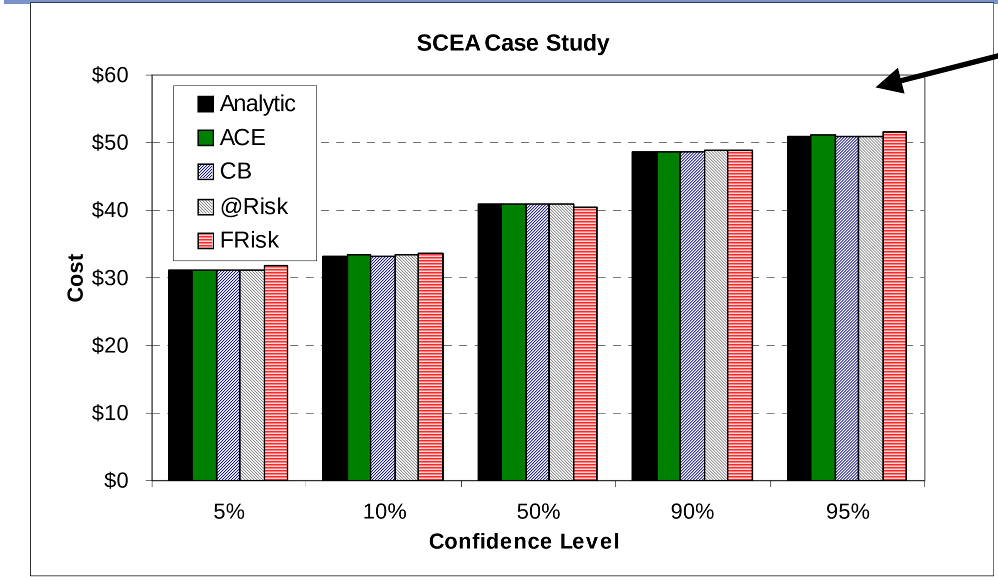
- **What are the risk tools and which should I choose?**
- **Crystal Ball, @Risk, ACE RI$K and FRisk *results* are compared…. Not their usability or suitability.**
- **Two case studies examined (SCEA paper has three):**
  - Published, simple and analytically solved case study (SCEA paper June 04, Reference 5).
  - Second example is based upon a more “realistic” cost model that cannot be solved analytically (Reference 7).
- **If handled properly, *all tools produce similar total cost distribution results* even when correlation is applied.**

Case Study Page CE V – 80
SCEA Training Manual

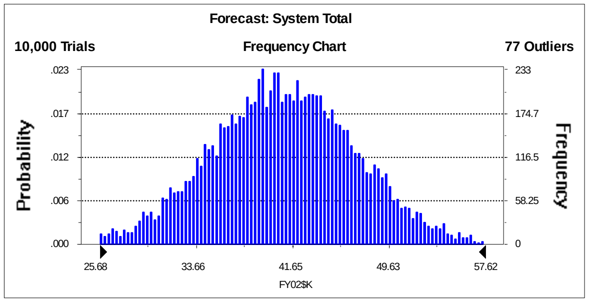
WBS	Equation/ Throughput	Distrn	Lower	Point Estimate	Upper	Analytic Stdev	ACE Stdev	CB Stdev	@Risk Stdev
Electronic System						6.015	6.013	6.026	5.998
PMP	12.50	Normal		12.500		2.569	2.570	2.569	2.569
SEPM	0.5*PMP			6.250		1.285	1.285	1.284	1.285
Sys Test & Evaluation				4.706		0.811	0.811	0.812	0.809
Sys Test & Eval	0.3125*PMP			3.906		0.803	0.803	0.803	0.803
Management Reser	0.80	Uniform	0.6	0.800	1.0	0.115	0.116	0.115	0.115
Data and Tech Orders	0.1*PMP			1.250		0.257	0.257	0.257	0.257
Site Survey & Activatio	6.60	Tiangular	5.1	6.600	12.1	1.505	1.505	1.505	1.505
Initial Spares	0.1*PMP			1.250		0.257	0.257	0.257	0.257
System Warranty	1.10	Uniform	0.9	1.100	1.3	0.115	0.116	0.115	0.115
Early Prototype Phase	1.50	Triangular	1.0	1.500	2.4	0.290	0.290	0.290	0.290
Operations Supt	1.20	Triangular	0.9	1.200	1.6	0.143	0.143	0.143	0.143
System Training	0.25*PMP			3.125		0.642	0.643	0.642	0.642

- **Combination of throughput and factor relationships**
- **No risk applied to the factors**
- **PMP drives about 70% of the model result, so 70% of the risk is modeled with a normal distribution making it reasonable that the total cost is likely to be normally distributed.**
- **Sys Test & Eval has an additive risk which is unusual in cost risk analysis. We generally assume the risk scales with the estimate.**

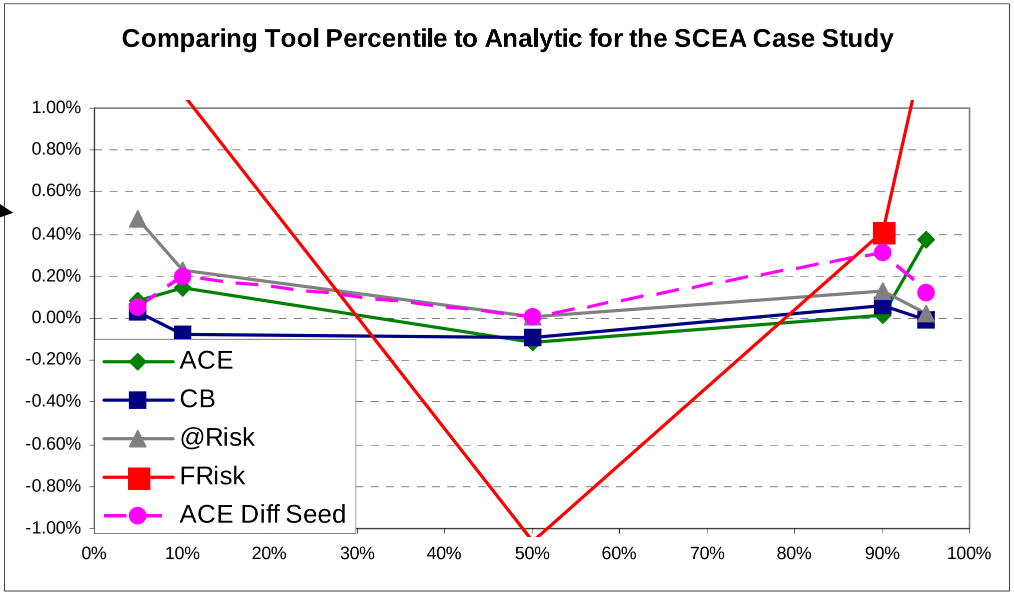
All Tools Perform Well



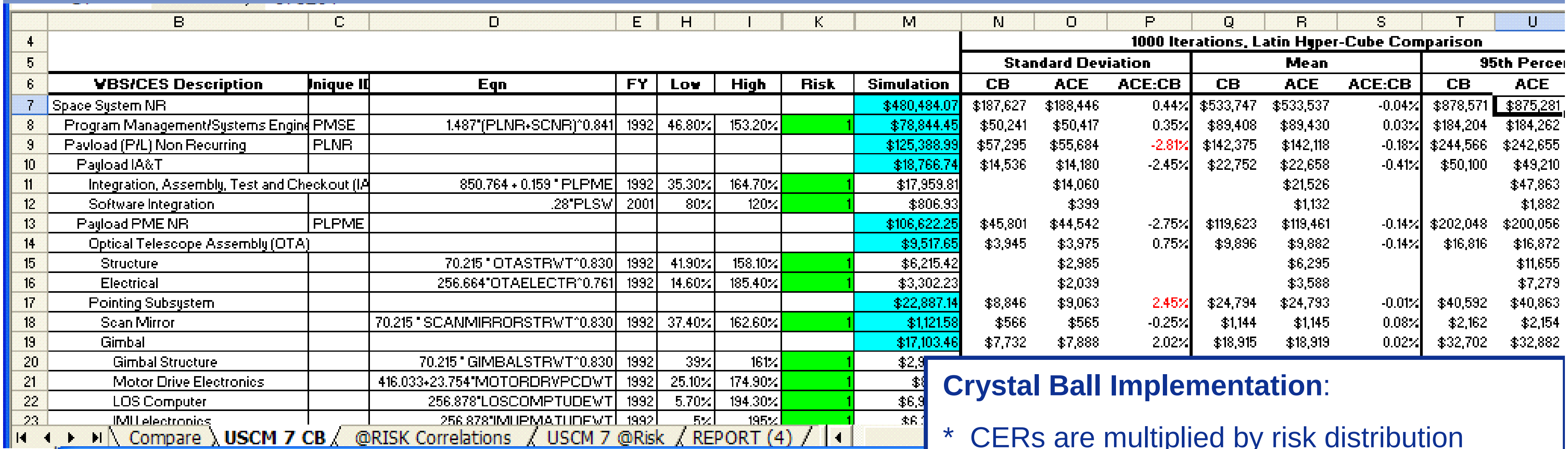
Use this scale if you wish to show that all models are not bad (FRisk is a little off because it assumes a log-normal distribution at the total level). Note that the simulation tool total result ***does*** appear “normal”.



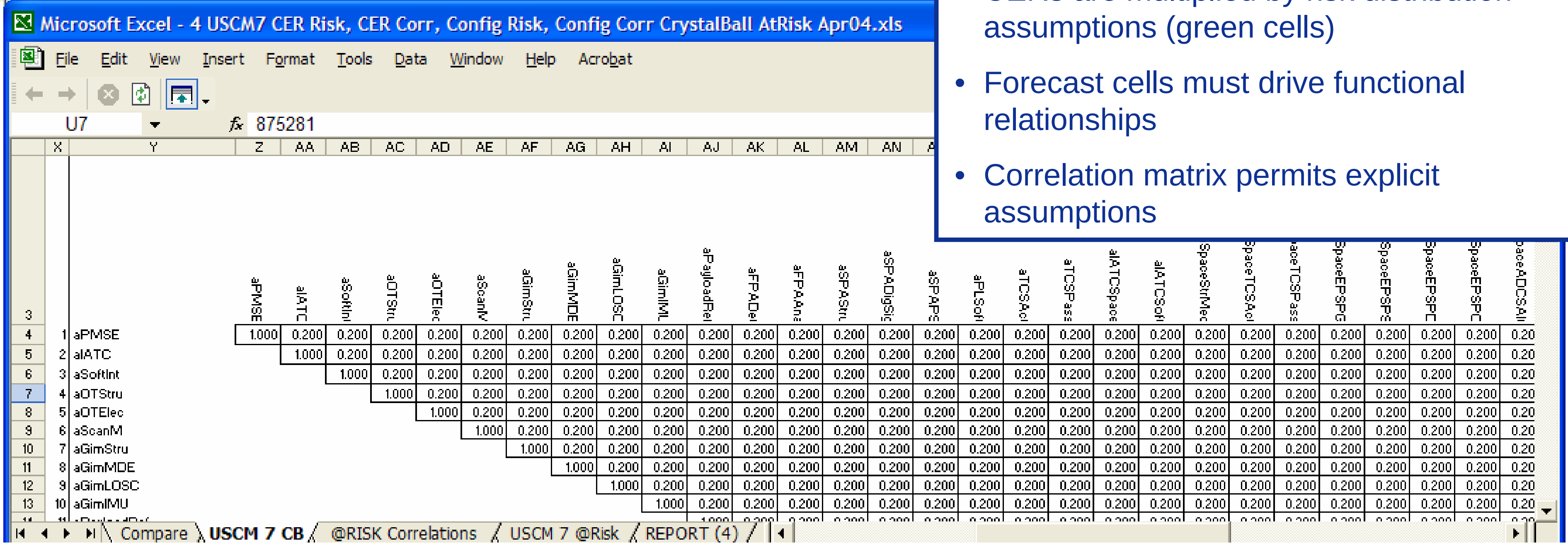
- Use this scale if you wish to show there are in fact differences amongst the models.
- However, note that the scale is so magnified, that simply changing the initial seed value (ACE is shown, but all behave the same) noticeably changes the results!



A “Realistic” Model



	B	C	D	E	H	I	K	M	N	O	P	Q	R	S	T	U
4									1000 Iterations, Latin Hyper-Cube Comparison							
5									Standard Deviation			Mean			95th Perce	
6	WBS/CES Description	Unique ID	Eqn	FY	Low	High	Risk	Simulation	CB	ACE	ACE:CB	CB	ACE	ACE:CB	CB	ACE
7	Space System NR							$480,484.07	$187,627	$188,446	0.44%	$533,747	$533,537	-0.04%	$878,571	$875,281
8	Program Management/Systems Engine	PMSE	1.487*(PLNR+SCNR)^0.841	1992	46.80%	153.20%	1	$78,844.45	$50,241	$50,417	0.35%	$89,408	$89,430	0.03%	$184,204	$184,262
9	Payload (P/L) Non Recurring	PLNR						$125,388.99	$57,295	$55,684	-2.81%	$142,375	$142,118	-0.18%	$244,566	$242,655
10	Payload IA&T							$18,766.74	$14,536	$14,180	-2.45%	$22,752	$22,658	-0.41%	$50,100	$49,210
11	Integration, Assembly, Test and Checkout (IA		850.764 + 0.159 * PLPME	1992	35.30%	164.70%	1	$17,959.81		$14,060			$21,526			$47,863
12	Software Integration		.28*PLSW	2001	80%	120%	1	$806.93		$399			$1,132			$1,882
13	Payload PME NR	PLPME						$106,622.25	$45,801	$44,542	-2.75%	$119,623	$119,461	-0.14%	$202,048	$200,056
14	Optical Telescope Assembly (OTA)							$9,517.65	$3,945	$3,975	0.75%	$9,896	$9,882	-0.14%	$16,816	$16,872
15	Structure		70.215 * OTASTRWT^0.830	1992	41.90%	158.10%	1	$6,215.42		$2,985			$6,295			$11,655
16	Electrical		256.664*OTAELECTR^0.761	1992	14.60%	185.40%	1	$3,302.23		$2,039			$3,588			$7,279
17	Pointing Subsystem							$22,887.14	$8,846	$9,063	2.45%	$24,794	$24,793	-0.01%	$40,592	$40,863
18	Scan Mirror		70.215 * SCANMIRRORSTRWT^0.830	1992	37.40%	162.60%	1	$1,121.58	$566	$565	-0.25%	$1,144	$1,145	0.08%	$2,162	$2,154
19	Gimbal							$17,103.46	$7,732	$7,888	2.02%	$18,915	$18,919	0.02%	$32,702	$32,882
20	Gimbal Structure		70.215 * GIMBALSTRWT^0.830	1992	39%	161%	1	$2,9								
21	Motor Drive Electronics		416.033+23.754*MOTORDRVPCDWT	1992	25.10%	174.90%	1	$8								
22	LOS Computer		256.878*LOSCOMPTUDEWT	1992	5.70%	194.30%	1	$6,9								
23	IMU electronics		256.878*IMUPMATUDEWT	1992	5%	195%	1	$6.1								



U7 fx 875281

			aPMSE	aIATC	aSoftInl	aOTStru	aOTElec	aScanM	aGimStru	aGimMDE	aGimLOSC	aGimIML	aPayloadRel	aFPADel	aFPAAna	aSPAStru	aSPADigSig	aSPAPS	aPLSoft	aTCSAct	aTCSPass	aIATCSpace	aIATCSoft	SpaceStrMec	SpaceTCSAct	aceTCSPass	SpaceEPSPG	SpaceEPSPS	SpaceEPSPC	SpaceEPSPC	aceADCSAll
4	1	aPMSE	1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.20
5	2	aIATC		1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.20
6	3	aSoftInt			1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.20
7	4	aOTStru				1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.20
8	5	aOTElec					1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.20
9	6	aScanM						1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.20
10	7	aGimStru							1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.20
11	8	aGimMDE								1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.20
12	9	aGimLOSC									1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.20
13	10	aGimIMU										1.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.20

Crystal Ball Implementation:

* CERs are multiplied by risk distribution assumptions (green cells)

- Forecast cells must drive functional relationships
- Correlation matrix permits explicit assumptions

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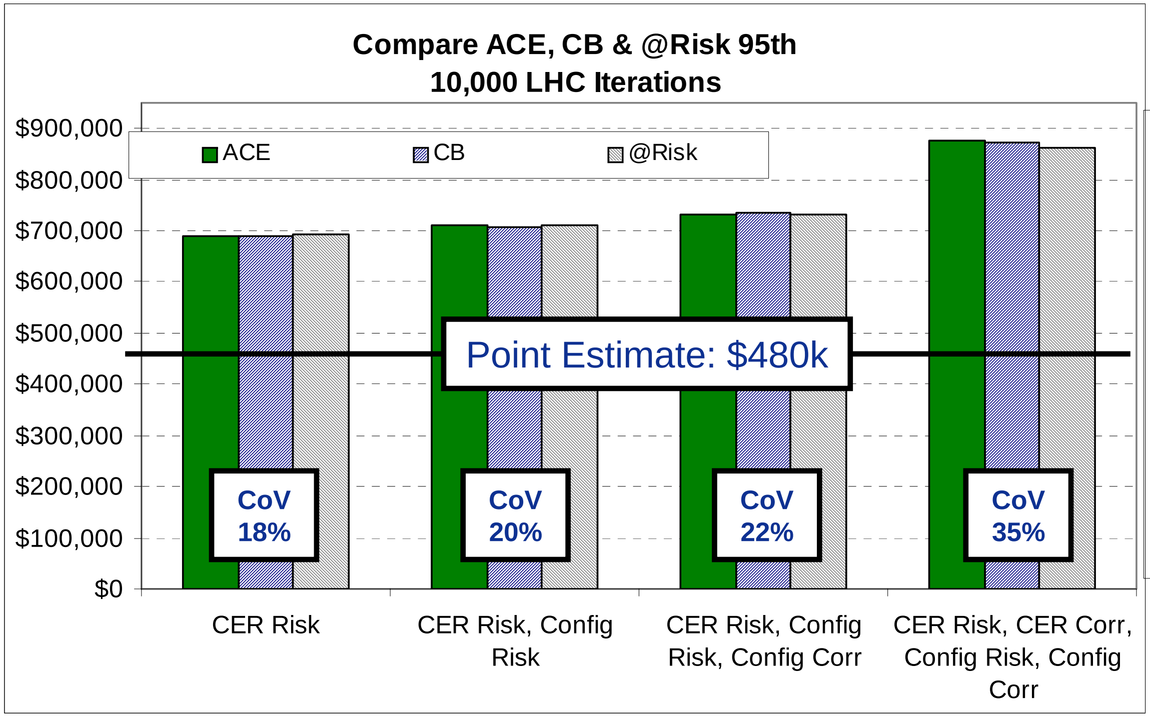
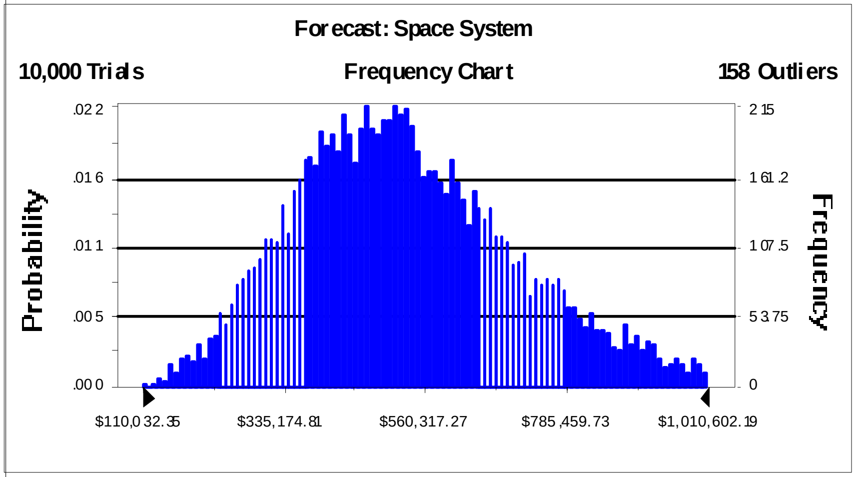
USCM 7 Comparison





- More than 30 linear, non-linear, throughput CERs and 30 input values
- Compared total cost result at the 95th percentile based upon a systematic layering of correlation assumptions
- All three tools produce remarkably similar results in each scenario.

Comparing Risk Tools

- **If you are consistent with:**
  - How to interpret the point estimate
  - Number of iterations.
  - If using Latin Hypercube [LHC], the number of partitions.
  - Inflation, learning, and other modeled adjustments.
  - How functional correlations are modeled
  - Distribution shape and bound assumptions.
  - Truncation assumptions.
- **If you follow the tool developer’s recommendation for inputting correlation:**

Crystal Ball, @Risk and ACE will give results well within the simulation tool error band.

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Backup Slides

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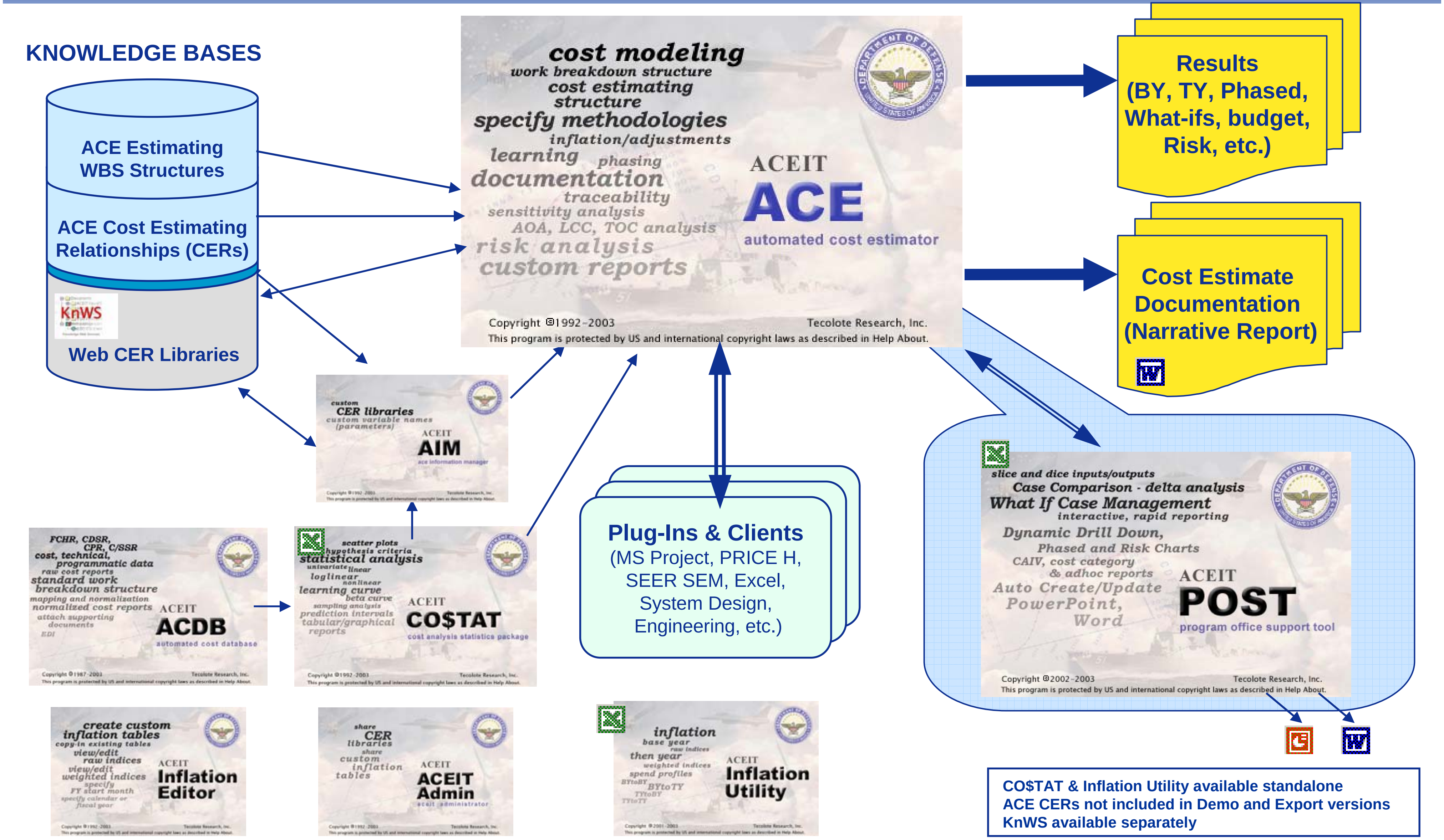
ACEIT Is Structured to Automate the Estimating Environment



KNOWLEDGE BASES

ACE Estimating WBS Structures

ACE Cost Estimating Relationships (CERs)

Web CER Libraries

cost modeling
work breakdown structure
cost estimating structure
specify methodologies
inflation/adjustments
learning
phasing
documentation
traceability
sensitivity analysis
AOA, LCC, TOC analysis
risk analysis
custom reports

ACEIT
ACE
automated cost estimator

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Results (BY, TY, Phased, What-ifs, budget, Risk, etc.)

Cost Estimate Documentation (Narrative Report)

custom
CER libraries
custom variable names (parameters)

ACEIT
AIM
ace information manager

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Plug-Ins & Clients
(MS Project, PRICE H, SEER SEM, Excel, System Design, Engineering, etc.)

slice and dice inputs/outputs
Case Comparison - delta analysis
What If Case Management
interactive, rapid reporting
Dynamic Drill Down,
Phased and Risk Charts
CAIV, cost category
& adhoc reports
Auto Create/Update
PowerPoint,
Word

ACEIT
POST
program office support tool

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FCHR, CDSR,
CPR, C/SSR
cost, technical,
programmatic data
raw cost reports
standard work
breakdown structure
mapping and normalization
normalized cost reports
attach supporting
documents
EDI

ACEIT
ACDB
automated cost database

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scatter plots
hypothesis criteria
statistical analysis
univariate
linear
loglinear
nonlinear
learning curve
beta curve
sampling analysis
prediction intervals
tabular/graphical
reports

ACEIT
CO$TAT
cost analysis statistics package

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create custom
inflation tables
copy-in existing tables
view/edit
raw indices
view/edit
weighted indices
specify
FY start month
specify calendar or
fiscal year

ACEIT
Inflation Editor

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share
CER
libraries
share
custom
inflation
tables

ACEIT
ACEIT Admin
aceit administrator

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inflation
base year
raw indices
then year
weighted indices
spend profiles
BYtoBY
BYtoTY
TYtoBY
TYtoTY

ACEIT
Inflation Utility

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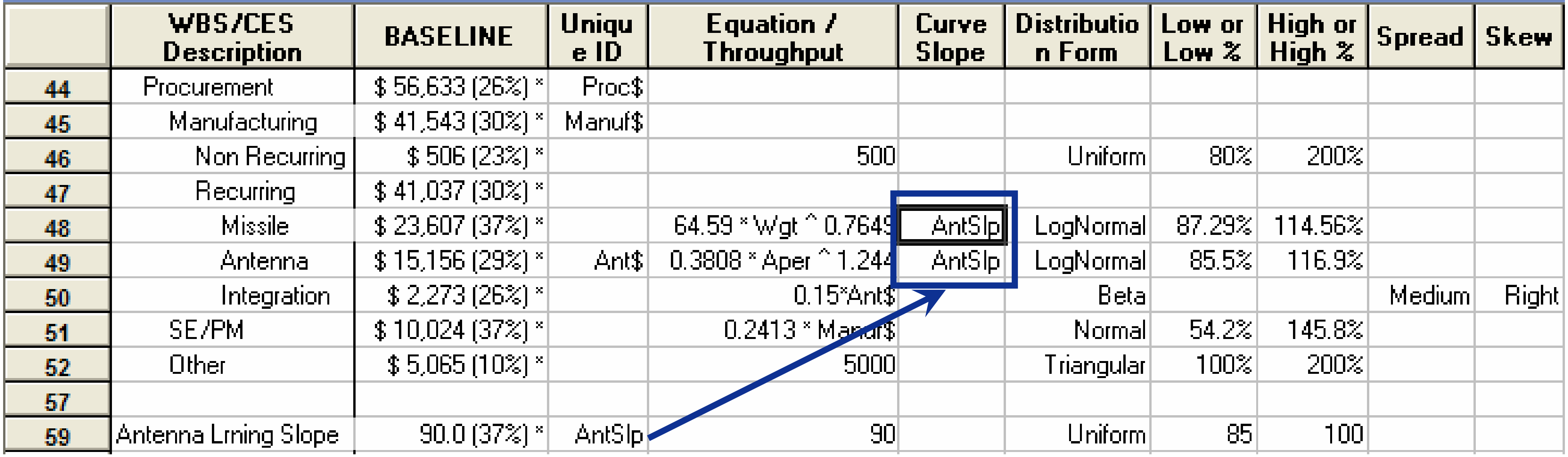
CO$TAT & Inflation Utility available standalone
ACE CERs not included in Demo and Export versions
KnWS available separately

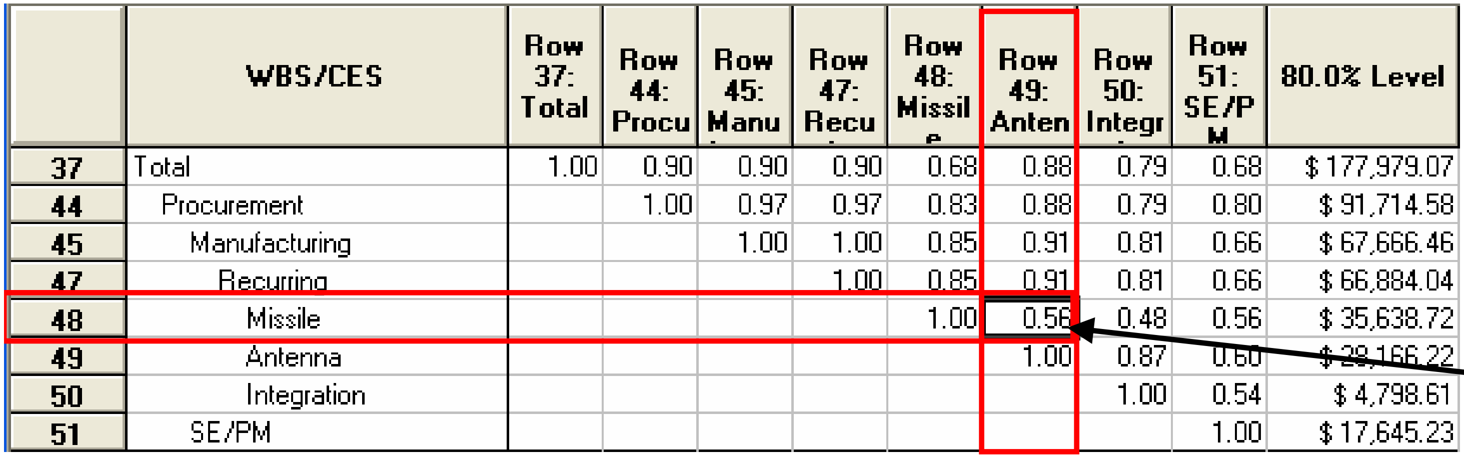
TECOLOTE RESEARCH, INC.

Unintentional Correlation?



	WBS/CES Description	BASELINE	Unique ID	Equation / Throughput	Curve Slope	Distribution Form	Low or Low %	High or High %	Spread	Skew
44	Procurement	$ 56,633 (26%) *	Proc$							
45	Manufacturing	$ 41,543 (30%) *	Manuf$							
46	Non Recurring	$ 506 (23%) *		500		Uniform	80%	200%		
47	Recurring	$ 41,037 (30%) *								
48	Missile	$ 23,607 (37%) *		64.59 * Wgt ^ 0.7649	AntSlp	LogNormal	87.29%	114.56%		
49	Antenna	$ 15,156 (29%) *	Ant$	0.3808 * Aper ^ 1.244	AntSlp	LogNormal	85.5%	116.9%		
50	Integration	$ 2,273 (26%) *		0.15*Ant$		Beta			Medium	Right
51	SE/PM	$ 10,024 (37%) *		0.2413 * Manuf$		Normal	54.2%	145.8%		
52	Other	$ 5,065 (10%) *		5000		Triangular	100%	200%		
57										
59	Antenna Lrning Slope	90.0 (37%) *	AntSlp	90		Uniform	85	100		

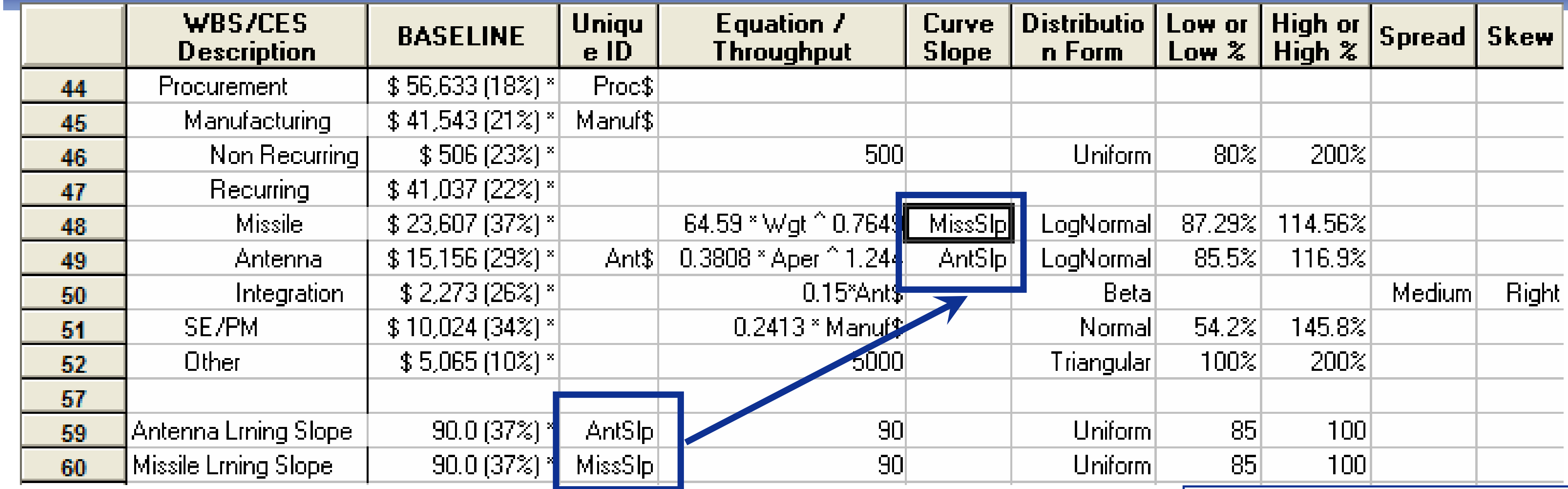
Same risk adjusted slope variable for missile/antenna.



	WBS/CES	Row 37: Total	Row 44: Procu	Row 45: Manu	Row 47: Recu	Row 48: Missile	Row 49: Anten	Row 50: Integr	Row 51: SE/PM	80.0% Level
37	Total	1.00	0.90	0.90	0.90	0.68	0.88	0.79	0.68	$ 177,979.07
44	Procurement		1.00	0.97	0.97	0.83	0.88	0.79	0.80	$ 91,714.58
45	Manufacturing			1.00	1.00	0.85	0.91	0.81	0.66	$ 67,666.46
47	Recurring				1.00	0.85	0.91	0.81	0.66	$ 66,884.04
48	Missile					1.00	0.56	0.48	0.56	$ 35,638.72
49	Antenna						1.00	0.87	0.60	$ 28,166.22
50	Integration							1.00	0.54	$ 4,798.61
51	SE/PM								1.00	$ 17,645.23

- **Much worry over possible *underestimated* correlation**
- **No apparent concern over possible *excessive* correlation**

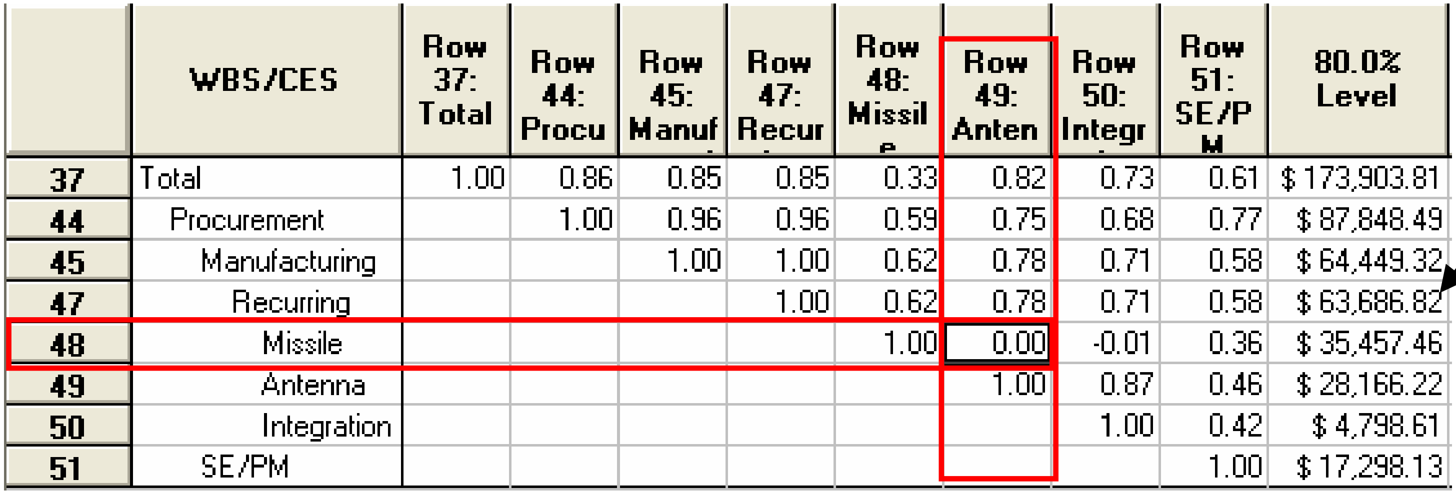
Removing Unintentional Correlation



	WBS/CES Description	BASELINE	Unique ID	Equation / Throughput	Curve Slope	Distribution Form	Low or Low %	High or High %	Spread	Skew
44	Procurement	$ 56,633 (18%) *	Proc$							
45	Manufacturing	$ 41,543 (21%) *	Manuf$							
46	Non Recurring	$ 506 (23%) *		500		Uniform	80%	200%		
47	Recurring	$ 41,037 (22%) *								
48	Missile	$ 23,607 (37%) *		64.59 * Wgt ^ 0.764	MissSlp	LogNormal	87.29%	114.56%		
49	Antenna	$ 15,156 (29%) *	Ant$	0.3808 * Aper ^ 1.24	AntSlp	LogNormal	85.5%	116.9%		
50	Integration	$ 2,273 (26%) *		0.15*Ant$		Beta			Medium	Right
51	SE/PM	$ 10,024 (34%) *		0.2413 * Manuf$		Normal	54.2%	145.8%		
52	Other	$ 5,065 (10%) *		5000		Triangular	100%	200%		
57										
59	Antenna Lrning Slope	90.0 (37%) *	AntSlp	90		Uniform	85	100		
60	Missile Lrning Slope	90.0 (37%) *	MissSlp	90		Uniform	85	100		

Need separate slope variable for the missile.

- Missile/ Antenna correlation now 0.
- Rec cost is now 5% less.



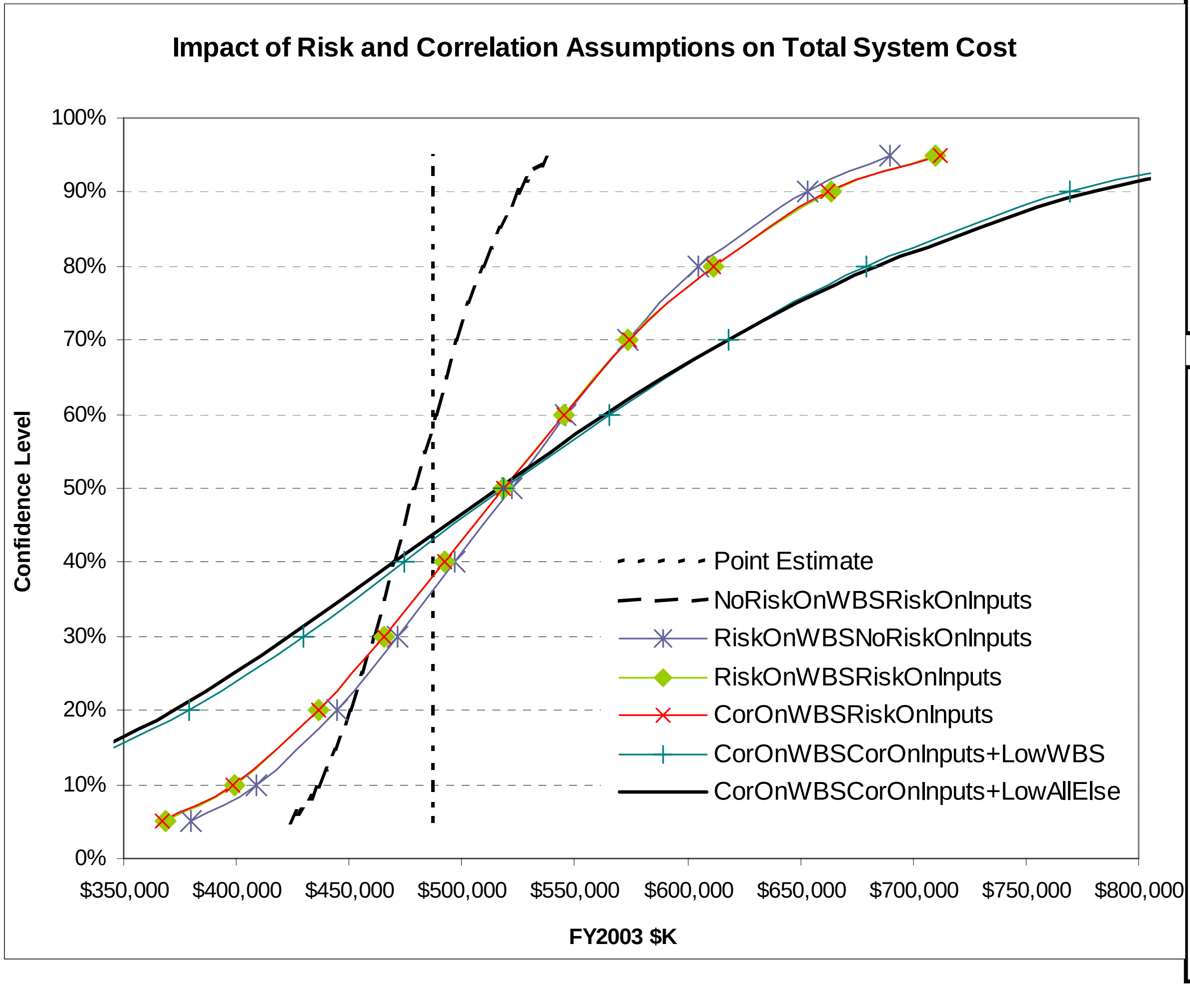
	WBS/CES	Row 37: Total	Row 44: Procu	Row 45: Manuf	Row 47: Recur	Row 48: Missile	Row 49: Anten	Row 50: Integr	Row 51: SE/PM	80.0% Level
37	Total	1.00	0.86	0.85	0.85	0.33	0.82	0.73	0.61	$ 173,903.81
44	Procurement		1.00	0.96	0.96	0.59	0.75	0.68	0.77	$ 87,848.49
45	Manufacturing			1.00	1.00	0.62	0.78	0.71	0.58	$ 64,449.32
47	Recurring				1.00	0.62	0.78	0.71	0.58	$ 63,686.82
48	Missile					1.00	0.00	-0.01	0.36	$ 35,457.46
49	Antenna						1.00	0.87	0.46	$ 28,166.22
50	Integration							1.00	0.42	$ 4,798.61
51	SE/PM								1.00	$ 17,298.13

Decisions Required:

Define Correlation Strength
- Strong (.9?)
- Moderate (.6?)
- Weak (.2?)

When to apply?

Impact on on Total Cost by Layering Risk Assumptions



Impact of Risk and Correlation Assumptions on Total System Cost

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%.

Applying risk to the CERs and inputs in ACE, before layering correlation, captures most of the risk. Forcing an additional 20% correlation across all WBS 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.