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autoRisk™

A Cost Estimation Risk Assessment Tool Implementing Lurie-Goldberg's Algorithm for Generating Correlated Vectors of Random Numbers

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OPS Consulting, L.L.C.

autoRisk Sponsor

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- The autoRisk tool was developed by OPS Consulting under subcontract to Wyle Laboratories. The tool was developed in support of a DoD research effort to extend the risk analysis capabilities of the SEER-SEM cost modeling tool

What is autoRisk?

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- OPS Consulting's autoRisk is a cost estimation, risk assessment tool, implementing Lurie-Goldberg's algorithms[1] for generating correlated vectors of random numbers

Why develop autoRisk?

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- autoRisk was developed to extend the "out-of-the-box" cost estimation engine of SEER-SEM to provide:
  - Monte Carlo simulation of WBS element cost drivers with user defined correlation
  - Monte Carlo simulation of WBS element rollup with automated or user defined correlation

WBS Element Levels

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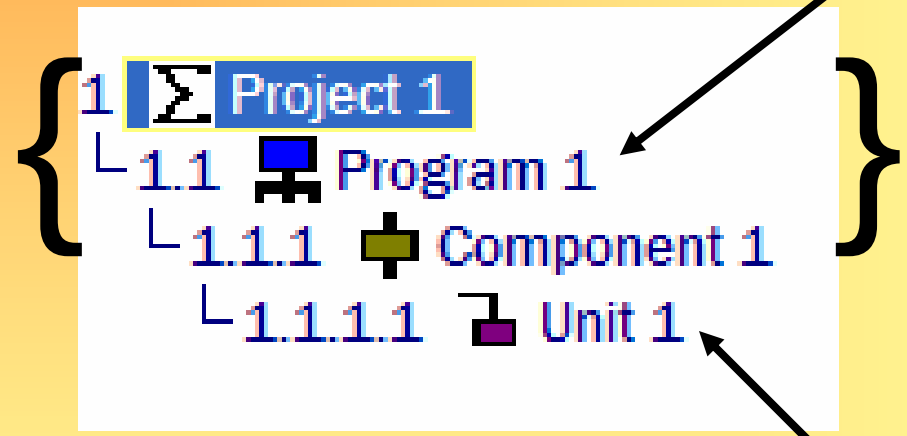
WBS Element Cost Drivers

SEER-SEM WBS Model

Rollup WBS Elements



Software Size Cost Drivers (At Lowest Level)

WBS Element Cost Drivers

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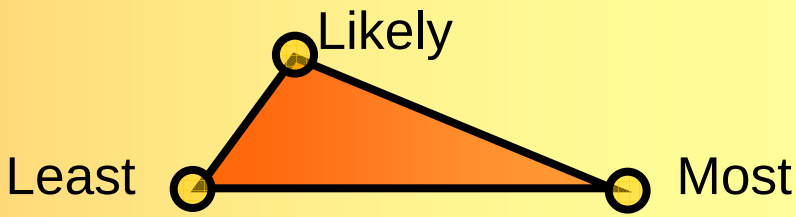
- Cost driver values define simulation ranges



Elementary Cost Drivers	Least	Likely	Most	Elementary Cost Drivers	Least	Likely	Most
New Lines of Code	9,000	10,000	20,000	Specification Level - Reliability	Low	Nom+	Hi+
New Functions	0	0	0	Test Level	Low	Nom+	Hi+
Analyst Capabilities	Low	Nom	Hi	Quality Assurance Level	Low	Nom+	Hi+
Analyst's Application Experience	Low	Nom	Hi	Rehost from Development to Target	Nom	Nom	Nom
Programmer Capabilities	Low	Nom	Hi	Reusability Level Required	Nom	Nom	Nom
Programmer's Language Experience	Nom	Hi	EHi	Language Type (complexity)	Low	Nom	Nom
Development System Experience	Nom	Hi	EHi	Development System Complexity	Nom	Nom	Hi
Target System Experience	Nom	Nom	EHi	Application Class Complexity	Nom	Nom	Hi
Practices & Methods Experience	Nom	Nom	Hi	Process Improvement	Nom	Nom	Hi
Modern Development Practices Use	Low	Nom	Hi	Special Display Requirements	Hi	Hi+	EHi
Automated Tools Use	Nom	Hi	Hi+	Memory Constraints	Nom	Nom	Nom
Logon thru Hardcopy Turnaround	VLo	VLo	Nom	Time Constraints	Nom	Nom	Hi
Terminal Response Time	Low	Low	Low	Real Time Code	Nom	Nom	Hi
Multiple Site Development	Nom	Hi	EHi	Target System Complexity	Nom	Nom	Hi
Resource Dedication	Nom	Nom	Nom	Target System Volatility	Low+	Nom	Hi
Resource and Support Location	Nom	Hi	EHi	Security Requirements	Nom	Nom	Nom
Development System Volatility	Low	Low+	Nom	Complexity (Staffing)	Nom	Nom	Nom
Process Volatility	Low	Nom	Hi	Requirements Definition Formality	Nom	Nom	Hi
Requirements Volatility (Change)	Hi-	Hi	VHi	Hardware Integration Level	VLo-	VLo-	VLo-

Cost Driver Correlation

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- Correlation Matrix (R_p) is user definable, but must be positive semi-definite

R_p

	AAE	PLE	DSE	TSE	MDPU	ATU	DSV	PV	SLR	TL	QAL	LT	DSC	ACC	PI	TSC	TSV	HIL
AAE	1													1				
PLE		1										1						
DSE			1				-0.5						1					
TSE				1													0.737	-0.373
MDPU					1	0.373										0.737		
ATU					0.373	1										0.083		
DSV			-0.5				1											
PV								1								0.083		
SLR									1	1	1							
TL									1	1	1							
QAL									1	1	1							
LT		1										1						
DSC			1										1					
ACC	1													1				
PI															1			
TSC					0.737	0.083		0.083								1		
TSV				0.737													1	-0.083
HIL				-0.373													-0.083	1

Use Cholesky decomposition to solve for L_p^T where:

$$R_p = L_p L_p^T$$

Multivariate normal random variables

$$Y_p = X L_p^T$$

Where X = set of η independent normal random variables

Cost Driver Simulation
Lurie-Goldberg

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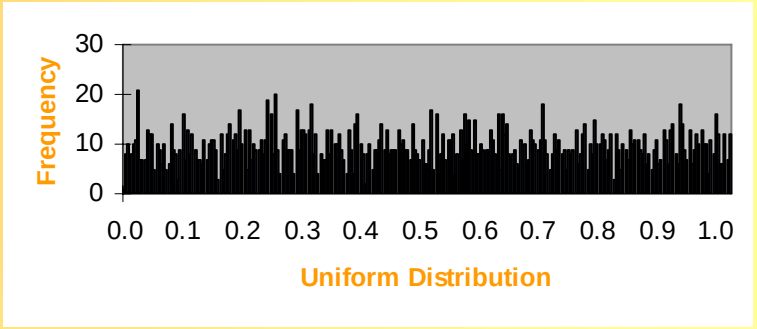
-For each WBS element
  -For each cost driver

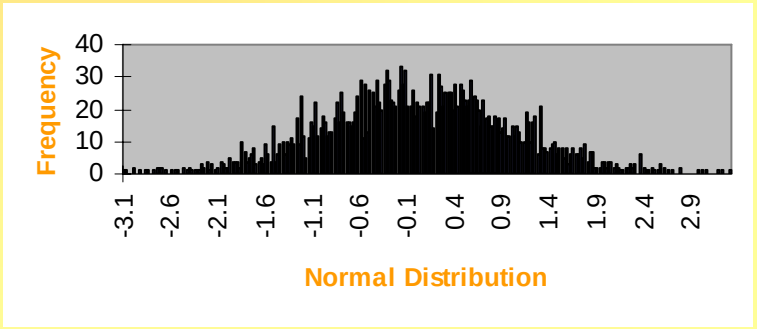
e.g.

5 WBS elements * 37 Cost Divers * 5000 iterations

Generate set of η uniformly distributed random numbers



Transform uniform distribution into normal distribution with Box Müller transformation[2]



Cost Driver Simulation
Lurie-Goldberg

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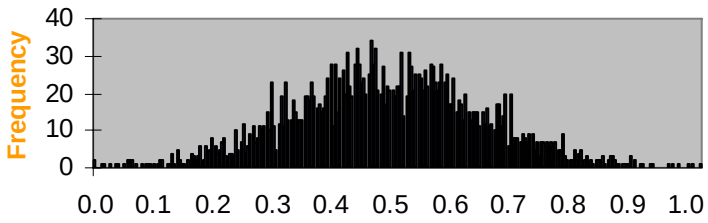
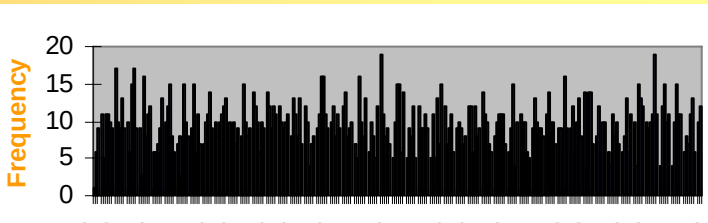
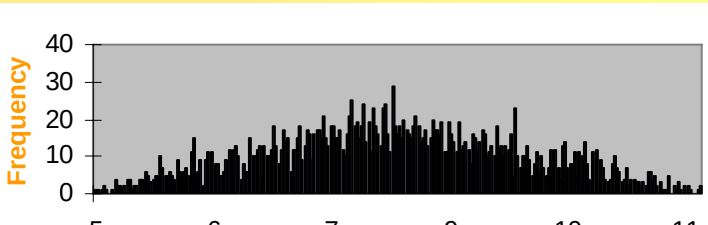
Apply Cholesky decomposition matrix to transform independent normal random variables to multivariate, correlated, normal random variables

Apply Moran inversion[3] to transform normal distribution into uniform distribution using unit normal c.d.f. Φ

Invert marginal uniform distribution into desired distribution (Triangular)







Cost Driver Simulation
Lurie-Goldberg Distortion

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Compute empirical correlation matrix on columns of marginal distribution

Evaluate distance measure between empirical correlation matrix and target correlation matrix

Perform constrained minimization of the distance measure

$Y_p = XL_p^T$

$R_p = L_pL_p^T$

RMSE >= 0.005

Cost Driver Correlation

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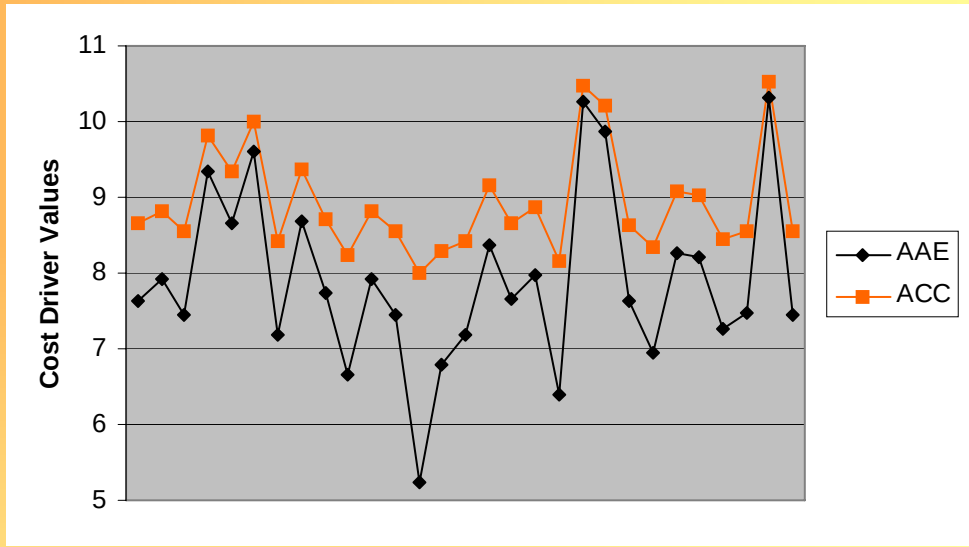
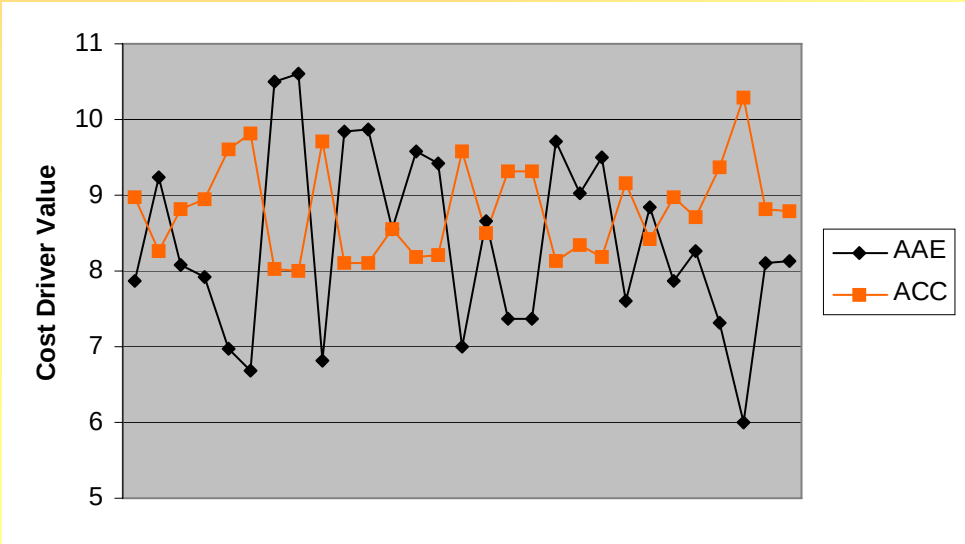
Correlation = 1.0



Correlation = -1.0



Cost Driver Simulation

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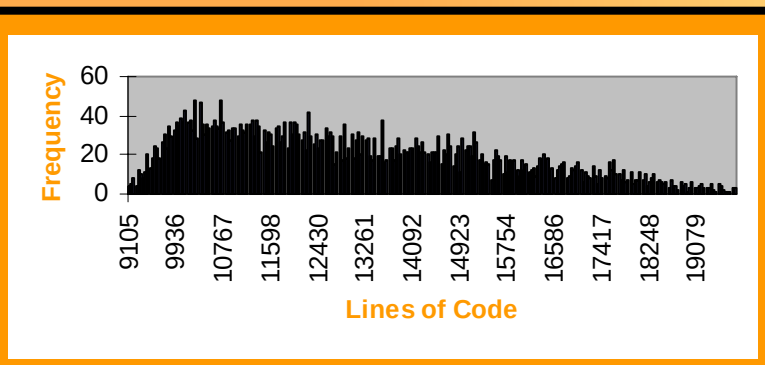

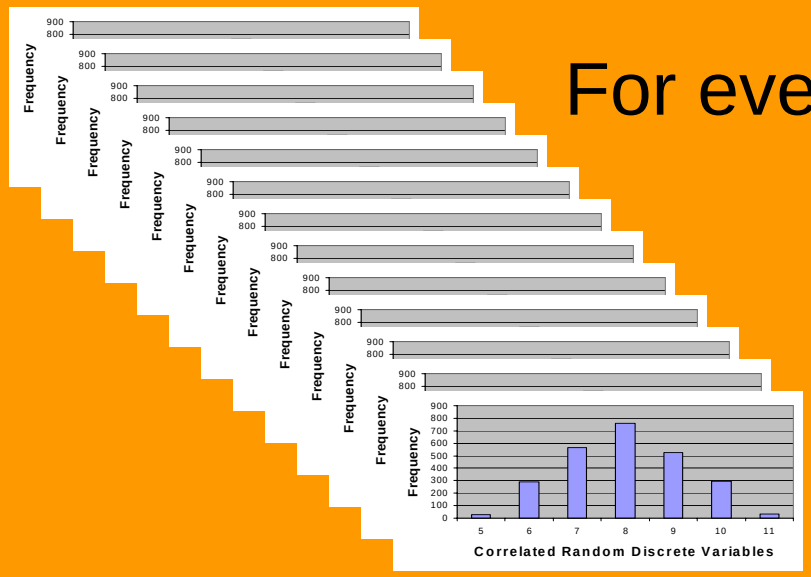

For every iteration

Cost Driver Simulation

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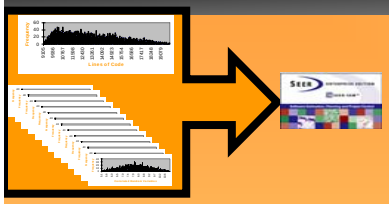
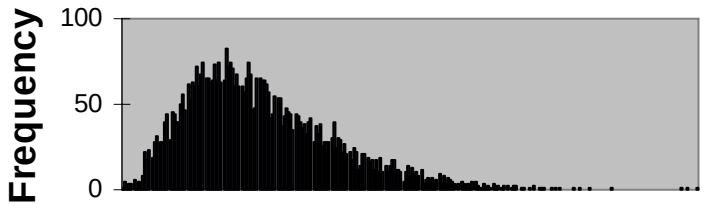
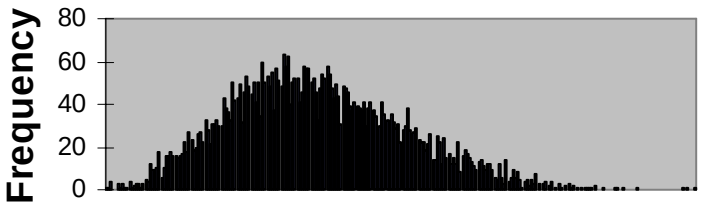
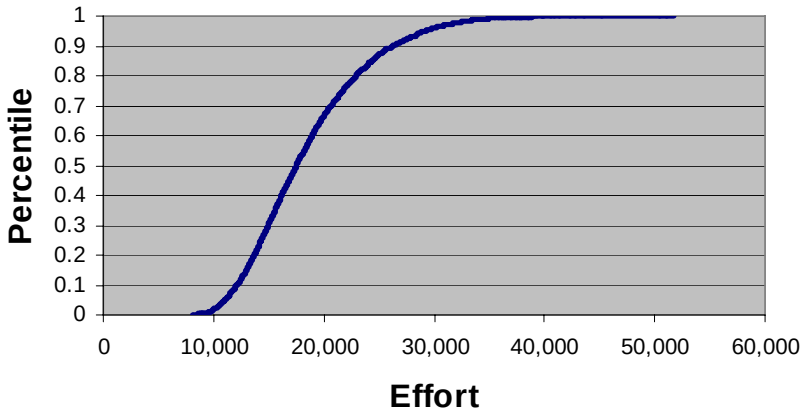
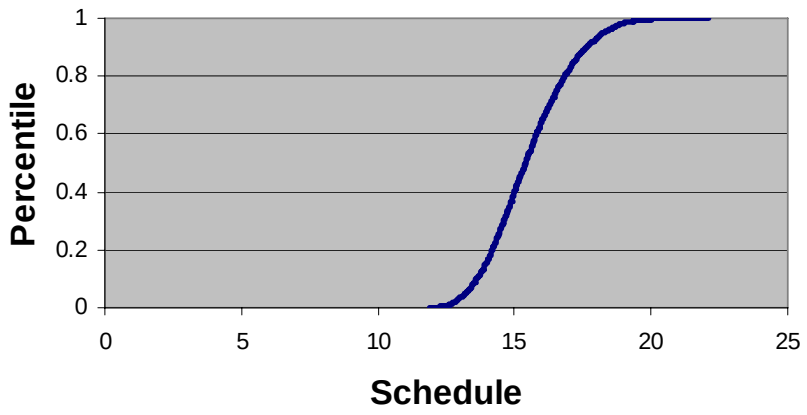


WBS 1.1









WBS Rollup Simulation

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-For each composite software element sub tree starting at deepest levels

-For n iterations

Generate set of uniformly distributed random numbers

Transform uniform distribution into normal distribution with Box Müller transformation

Apply Cholesky decomposition matrix to transform independent normal random variables to multivariate, correlated, normal random variables

Apply Moran inversion to transform normal distribution into uniform distribution using unit normal c.d.f. Φ

Invert marginal uniform distribution into desired distribution (Lognormal, Triangular, etc.)

WBS Rollup Simulation
Cholesky Decomposition

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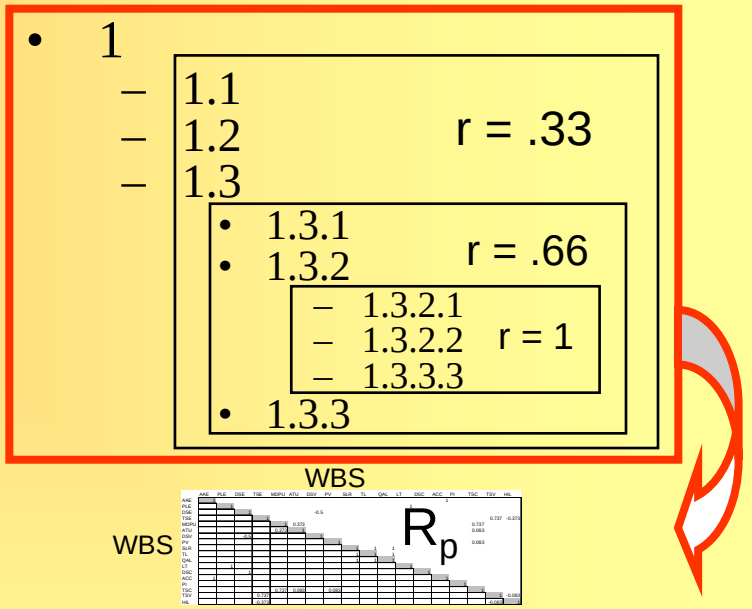
- Automatically computes correlation of WBS elements based on depth in tree (D)

Default correlation (r) at WBS level m

$r = \frac{m-1}{D-1}$ where: $1 < m <= D$

D = number of WBS levels



Auto generated correlation matrix $R_p = L_p L_p^T$

Multivariate correlated normal random variables $Y_p = XL_p^T$

Where: X = independent normal random variables

WBS Effort Rollup

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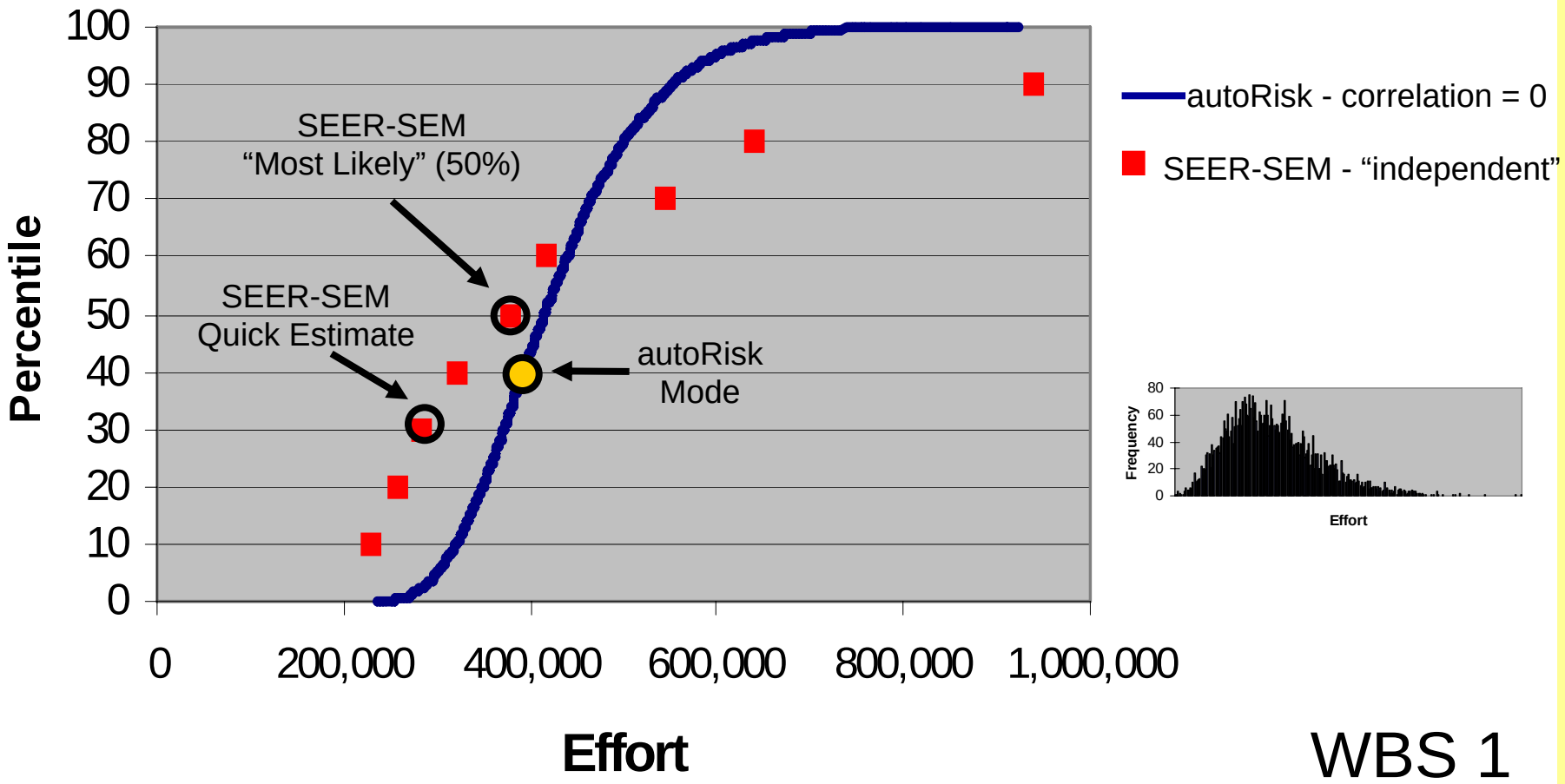

WBS 1

WBS Rollup Simulation Correlation Effects

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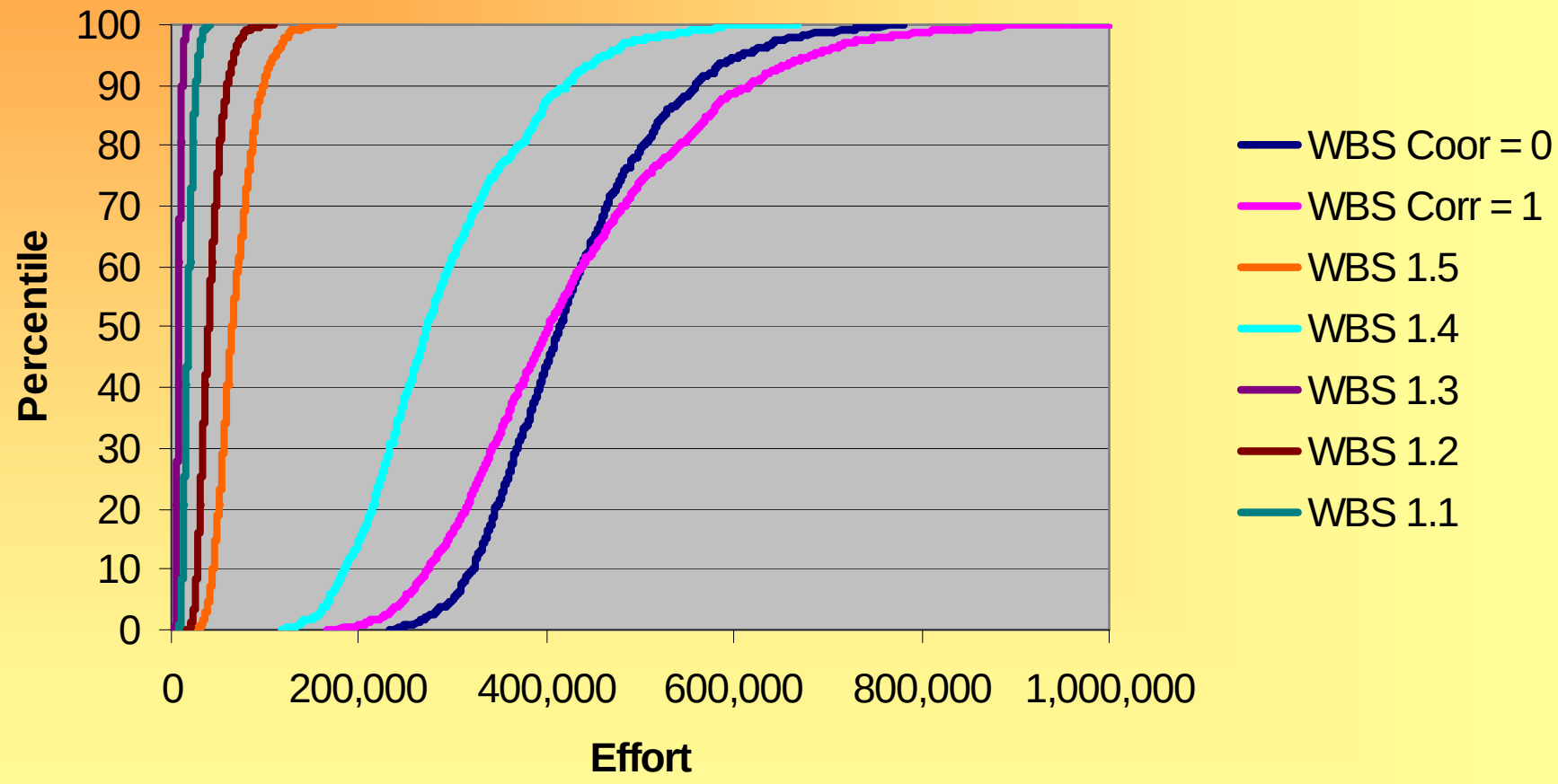

autoRisk GUI

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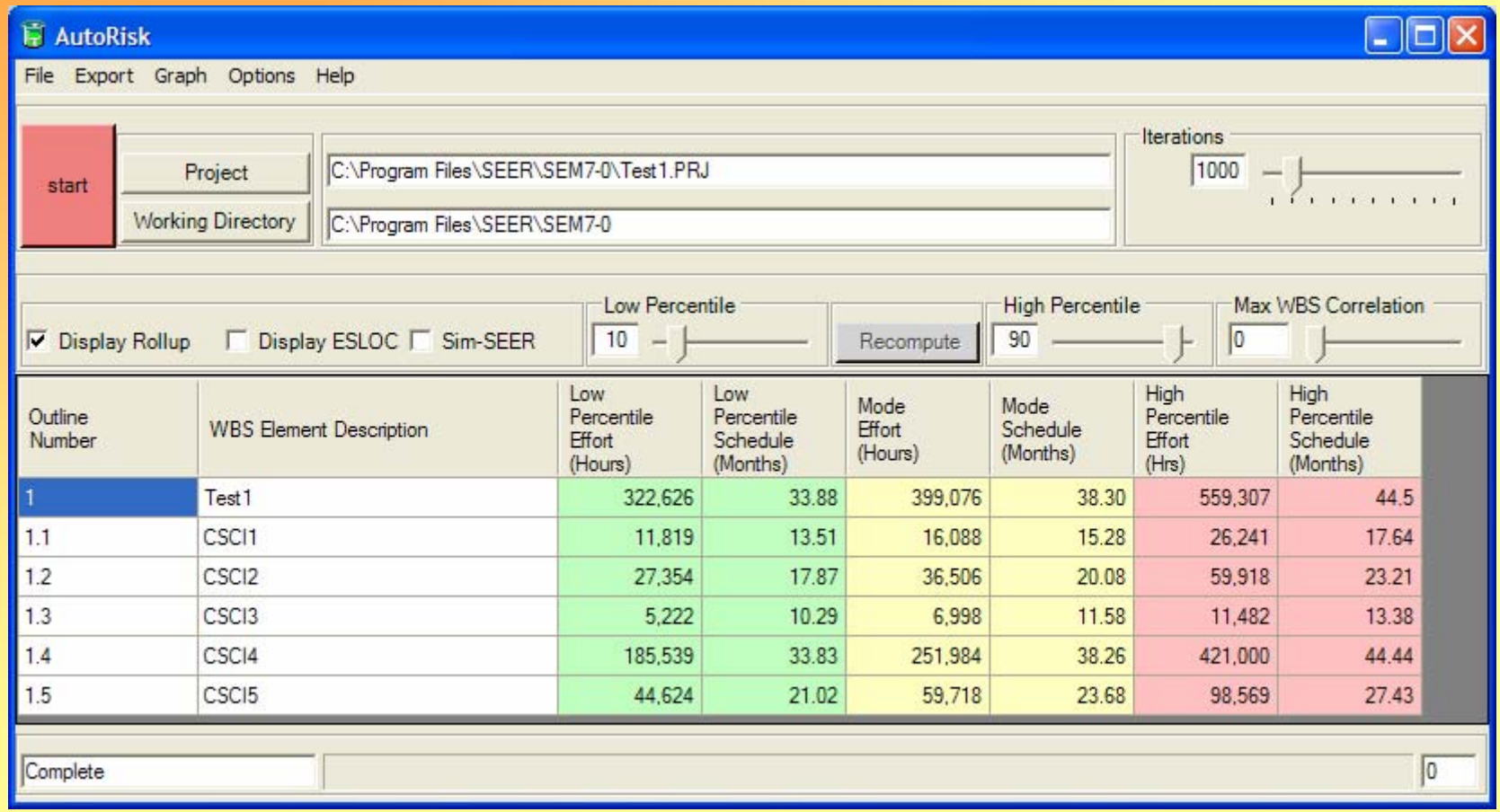

Outline Number	WBS Element Description	Low Percentile Effort (Hours)	Low Percentile Schedule (Months)	Mode Effort (Hours)	Mode Schedule (Months)	High Percentile Effort (Hrs)	High Percentile Schedule (Months)
1	Test1	322,626	33.88	399,076	38.30	559,307	44.5
1.1	CSCI1	11,819	13.51	16,088	15.28	26,241	17.64
1.2	CSCI2	27,354	17.87	36,506	20.08	59,918	23.21
1.3	CSCI3	5,222	10.29	6,998	11.58	11,482	13.38
1.4	CSCI4	185,539	33.83	251,984	38.26	421,000	44.44
1.5	CSCI5	44,624	21.02	59,718	23.68	98,569	27.43

autoRisk Summary

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- autoRisk provides a tailorable risk assessment framework for automatic simulation of estimate distributions
  - Integrated with widely accepted software cost modeling COTS application (SEER-SEM)
  - User tailorable
    - Simulation boundaries
    - Correlation definition and assignment

autoRisk - What's Next

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- Investigate/Develop interfaces to other COTS and open source software cost estimation tools
  - Developing user defined model import/definition
  - Developing COCOMO II implementation

Questions/Comments

References

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[1] **An Approximate Method for Sampling Correlated Random Variables from Partially-Specified Distributions**
Philip M. Lurie, Matthew S. Goldberg
Management Science, Vol. 44, No. 2 (Feb., 1998), pp. 203-218

[2] **Lecture Notes on Monte Carlo Methods (Simple Sampling of Gaussians)**
Jonathan Goodman
Courant Institute of Mathematical Sciences, NYU, Fall Semester (Aug., 2005), Chapter 2

[3] **Calculation of the normal distribution function**
P.A.P. Moran
Biometrika (1980), 67, 3 pp. 675-6

How to Contact OPS

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