LOCKHEED MARTIN

COSYSMO Risk/Confidence Estimation Prototype

John Gaffney

March 14, 2005

LOCKHEED MARTIN

Setting The Stage: The State of the Management World

- Managers and technical personnel need to make decisions under uncertainty.
- They should assess the extent of the uncertainty in the data and quantitative information that they rely on so that they can make better decisions.
  - Program managers often get a lot of (raw) data and frequently very little information.
  - Assess uncertainty using a systematic process. Recognize that there is uncertainty in both program input data (e.g.,goals, historical data, estimates) and program outcomes and assessing them is key.
  - Associate this process with “early/ leading indicators.”
- All too often, “the” value for effort or schedule is presented, unaccompanied by any statement of the degree of uncertainty in that value. Program managers and others involved in developing estimates for proposals should be able to quantify the degree of uncertainty in the estimates that they produce. Estimating cost, schedule, and other product or process variables as single numbers fails to provide decision makers with information sufficient to make good bidding and other decisions.

LOCKHEED MARTIN

The Problem of Unrealistic Pricing & Schedule

“Projects often overrun their cost estimates, sometimes by staggering amounts. This occurs even with carefully-constructed bottom-up cost estimates completed to a very detailed level by experienced project teams.”

"Initial cost and schedule estimates for major projects have invariably been over-optimistic. The risk that cost and schedule constraints will not be met cannot be determined if cost and schedule estimates are given in terms of single points rather than distributions."

"The purpose of a cost uncertainty analysis is to provide the project manager with a cost that has an acceptable probability of being exceeded." The notion that there is a probability of exceeding an EAC is a difficult one for some people. But, the fact is that every project has risk, and ignoring risk does not make it go away.”

Dr. David Hulett

LOCKHEED MARTIN

What is “Risk” ?

•Risk is commonly evaluated as the product of the likelihood (taken as the probability) of an occurrence of an event and the impact or consequence of the event with respect to a specific factor (cost, schedule, technical parameter, etc).

•A plot of occurrence probabilities and consequences is a “risk profile” or a “Farmer curve.” The probability is often referred to as the “exceedance” probability, because it is the ***probability*** that the ***consequence value*** will be exceeded*.

*Ayyub, Bilal M., Risk Analysis in Engineering and Economics, Chapman and Hall/CRC, 2003.

LOCKHEED MARTIN

"Risk" Vs. "Confidence," Alternative Views or Perceptions, page 1 of 2

- You can **consider uncertainty** in terms of the "risk" in a figure or the "confidence" in it.
- Example Definitions:
  - **Effort Risk**=Probability (complementary cumulative distribution) that the effort **will exceed** the indicated value. Called the "exceedance probability" in some risk literature.
  - **Effort Confidence**=Probability (cumulative distribution) that the effort **will not exceed** the indicated value. This is the upper bound of an effort estimate at the stated **confidence** level. Example: 90% confidence=10% risk.

LOCKHEED MARTIN

"Risk" Vs. "Confidence," Alternative Views or Perceptions, page 2 of 2

- It depends on with whom you are talking and how you want to communicate the data and the **best way that you can communicate the uncertainty in the data (and information)**.
- It depends on what question you are trying to answer. For example:
  - If you are a program manager or upper management of the contracting or bidding organization, you might be asking "What is my cost (effort) exposure or risk if I bid this figure?"
  - If you are the customer or acquirer or you are the bidder trying to communicate to this person, you might be asking "What is the bidder's confidence in this cost (effort) figure ?"
- That is, there are **two alternative points** of view. Both are correct. It depends to whom the message quantifying uncertainty is being conveyed.

LOCKHEED MARTIN

COSYSMO Risk Tool Prototype Overview

This excel-based tool is a prototype of an add-on to the COSYSMO systems engineering labor estimation model. It enables the user to quantify his belief in the uncertainties in the values of various parameters of the COSYSMO model, and hence in the value of the output of the model, systems engineering person months (PM). Each uncertainty is represented by two equivalent distributions, "**risk**"and the other for "**confidence,**" as was defined before.

The tool uses a three-point estimator to approximate the distribution of the values of each uncertain quantity for which data is applied in the model/tool.
The three values required from which the distribution function is approximated are:
the 5% fractile, the median, and the 95% fractile. Operationally, these values are obtained from a combination of expert opinion and historical data (as available and relevant). Due to the uncertainties that often prevail, the three points elicited are frequently somewhat loosely interpreted as the smallest, most likely, and largest, allowing for some margin below the smallest value and some beyond the largest.

The tool consists of five sheets:

-TOOL Description
-COSYSLABRISK
-COSSIZEDR
-COSTDRIV
-PLOTS

COSYSLABRISK

This is the "main" part of the model/tool. It computes both the PM Risk and PM Confidence distributions, based in part on distribution vales for the equivalent requirements size (see **COSSIZEDR** tool sheet description) and cost drivers product value (see **COSTDRIV** tool sheet description). It also computes a PM Overrun Risk, the range of probabilities for a range of possible overruns, relative to some target PM that the user enters.
This tool sheet determines the range for PM per the following equation:

Person Months, $PM=A*S^{E}*D$; where: D=cost driver product value,S=Equivalent Requirements Size, A=Baseline Unit PM per S value, and E=Exponent.

This tool sheet requires the user to enter the three-point distribution approximation values for A and E. The tool sheet obtains the three-point values for D and S from from the **COSTDRIV** and **COSTSIZEDR** tool sheets.
This tool sheet must be executed whenever you change the value of at least one parameter (ones that may be changed are in yellow cells). To execute this sheet press "cntrl+b."

LOCKHEED MARTIN

22-Feb-05

PROTOTYPE COSYSMO EFFORT RISK ESTIMATOR

Place value in each box in dicated in yellow.
DO NOT MAKE ENTRIES IN ANY OTHER CELLS.
Then, press cntrl+b to execute the tool and obtain the .
person month risk and cumulative probabilities

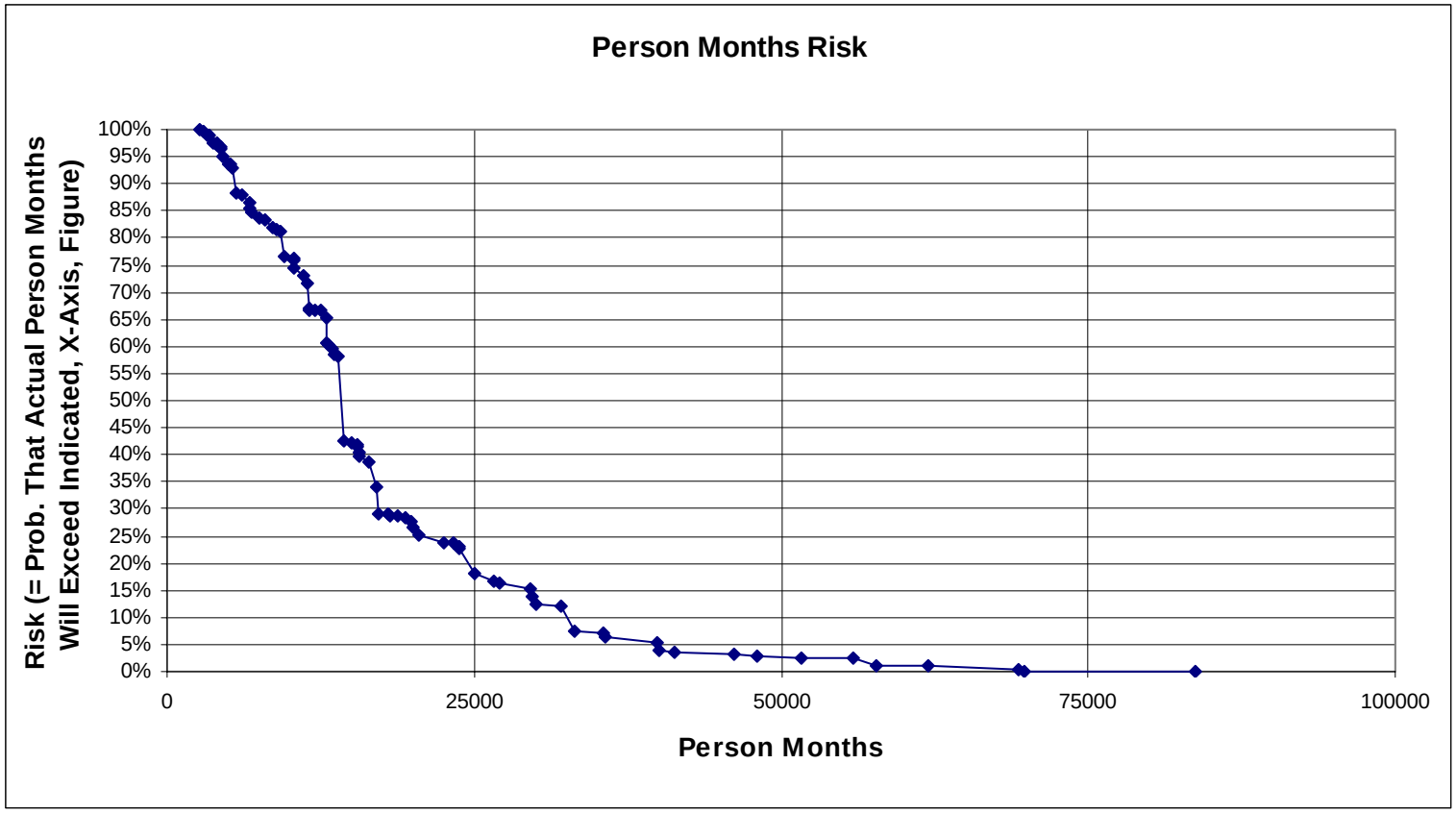
Risk Component		Range Estimate Values		
Number	Name	Low Estimate	Likely Estimate	High Estimate
1	A	2.40	3.00	3.60
2	S	3829	4244	5039
3	E	0.95	1.00	1.10
4	D	0.4420	1.1310	1.9688

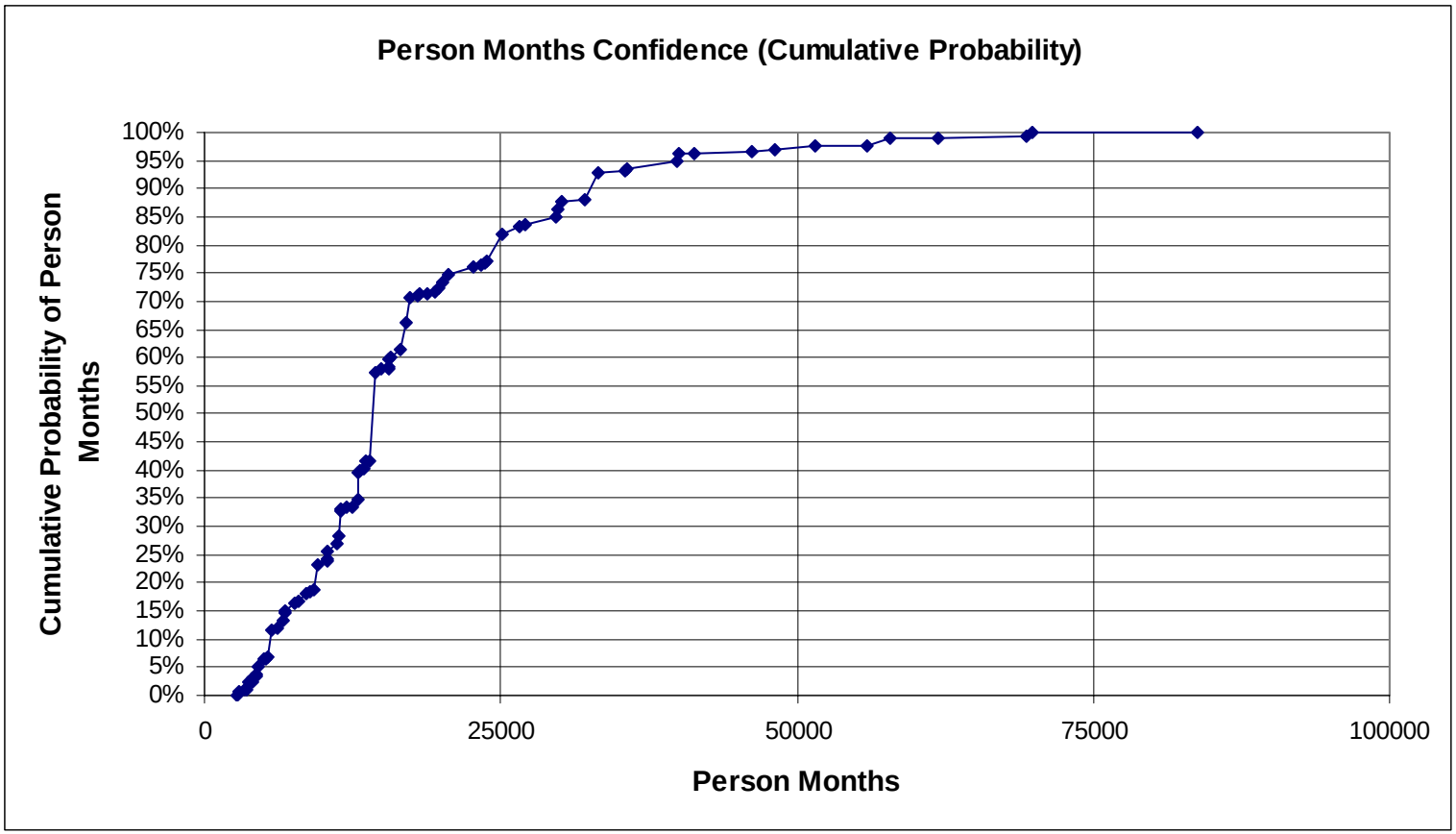
Person Months,PM=A*S^{E}*D; where: D, cost driver product, an S, size driver, are obtained from other tool sheets.

Most Likely PM
14399
PM Target
25000

Summary COSYSMO Person Months Risk/Confidence Statistics

Minimum PM=	**2689**
Risk=	**99.88%**
Confidence=	**0.12%**
Most Likely PM=	**14399**
Risk=	**42.52%**
Confidence=	**57.48%**
Maximum PM=	**83762**
Risk=	**0.00%**
Confidence=	**100.00%**
20% Risk/ 80% Confidence PM=	**23808**
30% Risk/ 70% Confidence PM=	**17096**
50% Risk/ 50% Confidence PM=	**13902**
95% Risk/5% Confidence PM=	**4447**
5% Risk/95% Confidence PM=	**39838**





LOCKHEED MARTIN

COSSIZEDR

This tool sheet develops the distribution function for the values of the four drivers from which the value for Equivalent Requirements is computed: The drivers are: system requirements, system interfaces, system specific algorithms, and operational scenarios. Four distributions are developed, one for each driver. The three points for each of them is a weighted sum for the counts of the "Easy," "Nominal," and "Difficult" values for each of the four drivers. The distribution approximation obtained has 81 points (81=3*3*3*3). This number of points provides a relatively smooth distribution curve.

This tool sheet must be executed whenever you change the value of at least one parameter (ones that may be changed are in yellow cells). To execute this sheet press "cntrl+a."

LOCKHEED MARTIN

COSYSMO Equivalent Requirements [1] Size Range/Risk Estimator 22-Feb-05

cntrl+a macro1

Size Driver Weights

Driver Name	Easy	Nominal	Difficult
# of System Requirements	0.50	1.00	4.23
# of System Interfaces	1.50	3.90	8.20
# of System-Specific Algorithms	3.00	5.80	16.60
# of Operational Scenarios	10.30	24.60	53.80

Note: These weights should not be modified without the agreement of the COSYSMO model owner.

(1): Number of Equivalent Requirements=Weighted Sum of Each of Four Easy,Nominal, and Difficult Size Driver Values.

Size Driver Range Values Data Entry

Driver Name	Range Values[1]	Number of Driver Items At Difficulty Level [2] Easy	Nominal	Difficult	Estimator Range Value [3]	Size Driver Value [4]	Data Entry Error Message Board [5]
# of System Requirements	Low Estimate	47.5	71.25	261.25	95.00%	1200	
	Likely Estimate	50	75	275	100.00%	1263	
	High Estimate	65	97.5	357.5	130.00%	1642	
# of System Interfaces	Low Estimate	27	54	72	90.00%	842	
	Likely Estimate	30	60	80	100.00%	935	
	High Estimate	33	66	88	110.00%	1029	
# of System-Specific Algorithms	Low Estimate	12.75	17	25.5	85.00%	560	
	Likely Estimate	15	20	30	100.00%	659	
	High Estimate	18.75	0	0	125.00%	824	
# of Operational Scenarios	Low Estimate	7.5	11.25	12.75	75.00%	1040	
	Likely Estimate	10	15	17	100.00%	1387	
	High Estimate	15	22.5	25.5	150.00%	2080	

Caution: Enter data in yellow cells only!

Size Data Entry Notes:

(1): The probability distributions for each of the four size drivers are estimated based on the nominal (assumed to be the mode) and the Low (assumed to be the 5% fractile), and the High (assumed to be the 95% fractile). This is done for the count values that you enter for easy, nominal, and difficult levels of difficulty.

(2): The size driver values for the Low Range (5% fractile) and the High Range (95% fractile) are entered as percents of the nominal values. The estimator tool proportions the counts for Easy, Nominal, and Difficult.

(3): The percentages for the Low and the High range values are entered as percents of the Nominal range value.

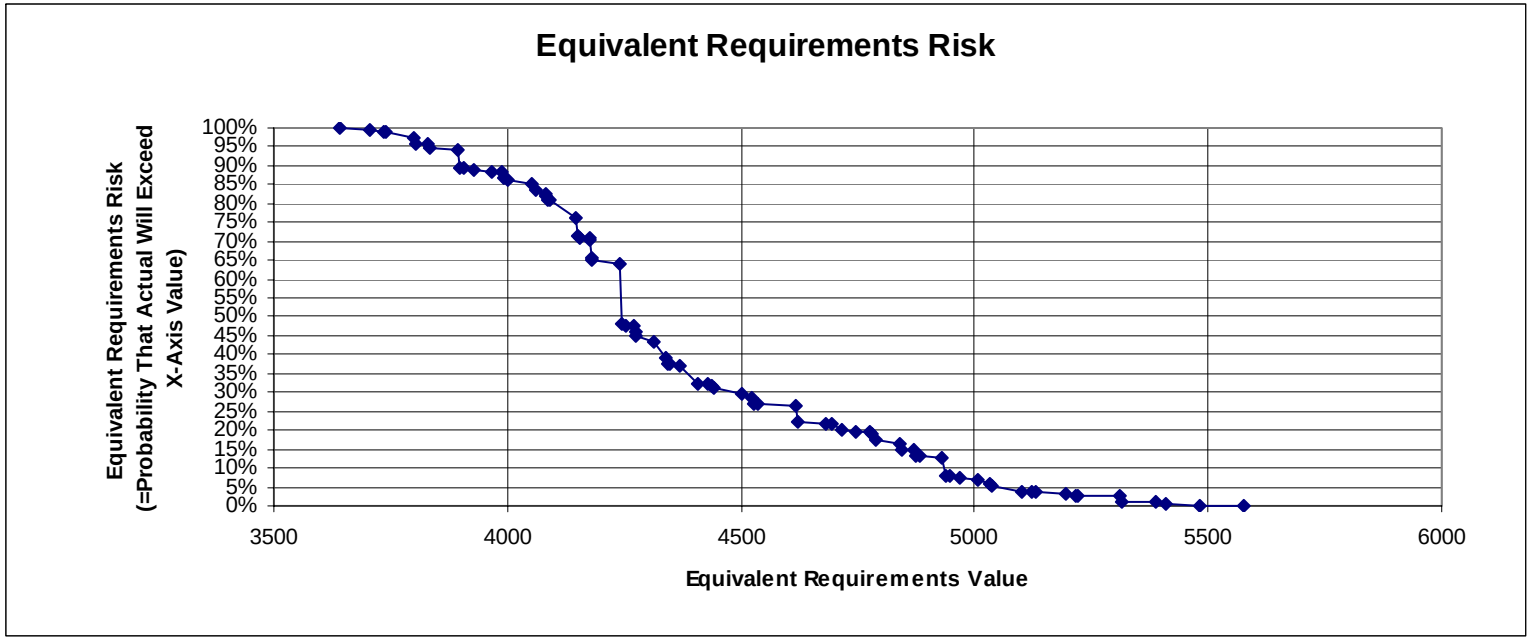
(4): The size driver value is equal to the weighted sum of the number of Easy, Nominal, and Difficult size driver counts for each of the four size drivers. The weights used are provided above.

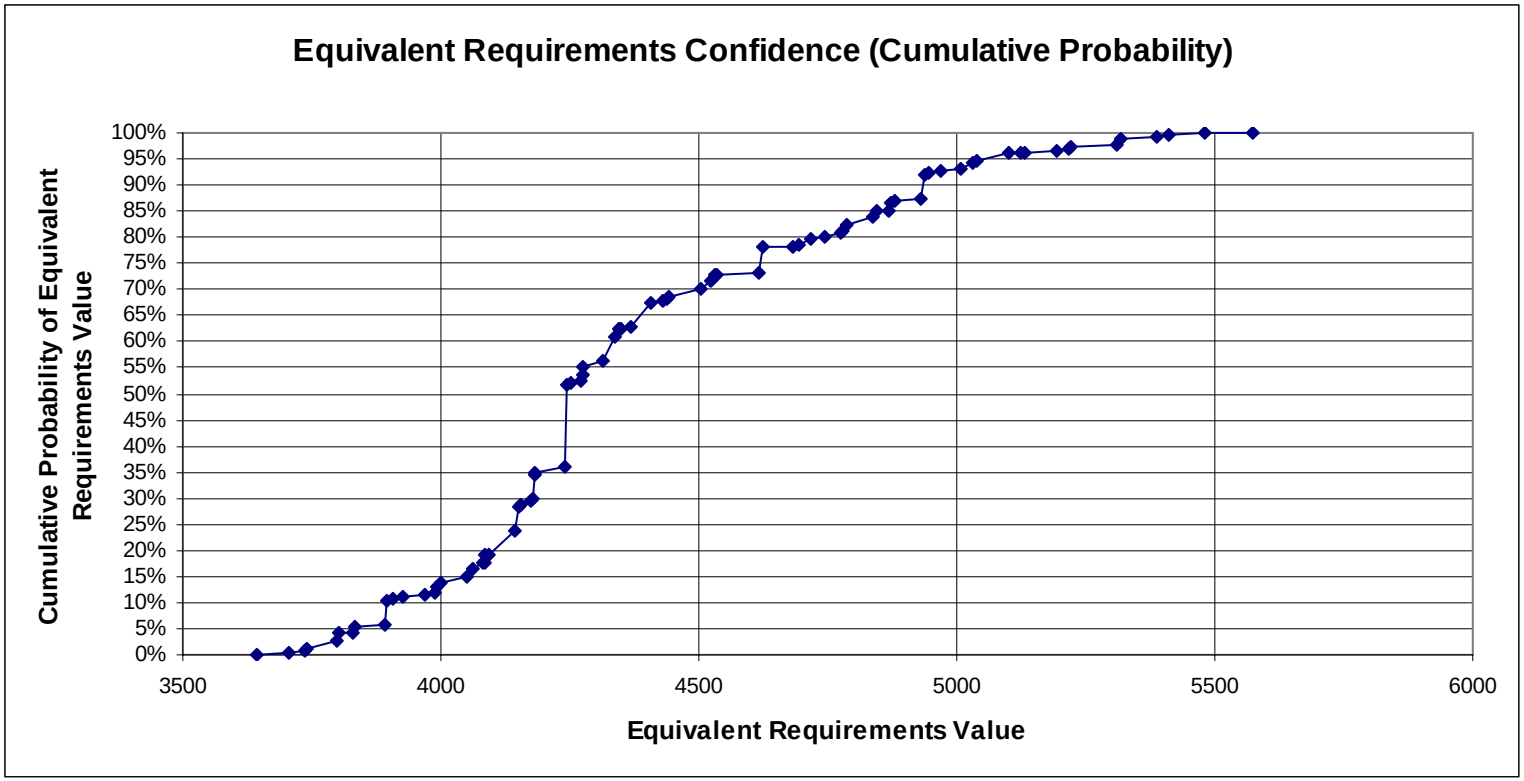
(5): Error messages are given if you enter a Low Range Value >100% of the Nominal and/or if you enter a High Range Value <100% of the Nominal.

LOCKHEED MARTIN

Summary COSYSMO Equivalent Requirements Size Risk/Confidence Statistics

Minimum Size=	3642
Risk=	99.88%
Confidence=	0.12%
Most Likely Size=	4244
Risk=	48.15%
Confidence=	51.85%
Maximum Size=	5574
Risk=	0.00%
Confidence=	100.00%
20% Risk/ 80% Confidence Size=	4716
30% Risk/ 70% Confidence Size=	4441
50% Risk/ 50% Confidence Size=	4239
95% Risk/5% Confidence Size=	3829
5% Risk/95% Confidence Size=	5039





LOCKHEED MARTIN

COSTDRIV

This tool sheet develops the distribution for the product of four of the COSYSMO cost drivers: Requirements Understanding, Technology Risk, Personnel/Team Capability, and Tool Support. More or even all of the cost drivers could be covered in a future prototype or final version of COSYSMO as may be desired. The four chosen were somewhat arbitrarily selected to illustrate the process of estimating the uncertainty of cost driver values and the application of the uncertainty in determining the uncertainty of the value of Person Months by COSYSMO.

This tool sheet must be executed whenever you change the value of at least one parameter (ones that may be changed are in yellow cells). To execute this sheet press "cntrl+c."

LOCKHEED MARTIN

PROTOTYPE COSYSMO COST DRIVER RISK ESTIMATOR

22-Feb-05

Place one "X" in each row to select the lower, the most likely, and Upper values covering the range of your uncertainty in the value of each of the four cost drivers.

Then, press cntrl+c to execute the tool and obtain the risk curve and cumulative probabilities for the product of the values of these cost drivers.

DO NOT MAKE ENTRIES IN ANY CELLS EXCEPT THOSE INDICATED IN YELLOW.

Note: Values inidcated in **red** from COSYSMO team; others are hypothetical.

Driver Number	Driver Name	Values XL	VL	L	N	H	VH	XH
1	**Reqm'ts. Under.**	1.9	1.71	1.30	1.00	0.75	0.65	0.50
	Low Estimate			x				
	Likely Estimate				x			
	High Estimate						x	
2	**Technol. Risk**	0.5	0.68	1.26	1.00	1.3	1.75	2.00
	Low Estimate		x					
	Likely Estimate					x		
	High Estimate						x	
3	**Pers/Team Cap.**	1.59	1.5	1.12	1.00	0.87	0.68	0.62
	Low Estimate		x					
	Likely Estimate				x			
	High Estimate						x	
4	**Tool Support**	1.43	1.4	1.1	1.00	0.87	0.75	0.62
	Low Estimate				x			
	Likely Estimate					x		
	High Estimate						x	
						Most Likely Driver Product Value=		1.131