Enhancements to COSYSMO
(For Risk and Reuse)

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Agenda/Background

- This presentation describes enhancements that have been made to the “Academic COSYSMO” systems engineering estimation model/tool, developed by Dr. Ricardo Valerdi.
- The enhancements relate to concerns that have been discussed at various COSYSMO working group and PSM meetings.
- The enhancements have been implemented in a tool, “COSYSMOR,” or “COSYSMO Risk and Reuse,” developed by Lockheed Martin, distributed by Dr. Valerdi, and available to any one who wants it.
- A major driver for the development of COSYSMOR was to get away from “single point” cost estimates in order to better recognize the uncertainty associated with effort, schedule, and cost estimates.
- Please consider attending the workshop, *The Breakout Year For COSYSMO* tomorrow PM and Thursday PM.

COSYSMOR Was Developed To Address These Concerns:

- Effort (Cost) Estimates are Inherently Uncertain
  - Judgment is enhanced if uncertainty is recognized
    - Traditional estimates are unaccompanied by any statement of the degree of uncertainty in these values and the overrun exposure they imply
  - So, it is desirable to estimate the risk or probability of exceeding a target labor or cost value
- Not all Requirements are the same
  - They are not just “new,” but can be “deleted,” “modified,” or “reused” from a prior version of this or another system.
  - Their costs differ.
- Estimators need to be able to allocate estimated systems engineering labor across development activities and across time or phases

Summary of Functions Provided By COSYSMOR

The COSYSMOR model/tool provides four major additional functions beyond those provided by Academic COSYSMO:

1. **Estimation of Cost/Effort and Schedule Uncertainties: "Risk" and "Confidence":** Provides quantification of the impacts of uncertainties in the values of key model parameter values. They are multiple cost and schedule values with associated probabilities.
2. **Representation of Multiple Types of Size Drivers:** Provides for entering counts of: new, modified, reused, and deleted types for each of the four size driver categories.
3. **Labor Scheduling**: Provides the spread of systems engineering labor for five systems engineering activities and across four development phases (time).
4. **Labor Allocation**: Provides for the user to select the percentage allocations of the twenty activity/phase pairs or effort elements.

COSYSMOR Data Entry

ENTER SIZE PARAMETERS FOR SYSTEM OF INTEREST

	Low			Likely*			High		
	Easy	*Nominal*	*Difficult*	*Easy*	*Nominal*	*Difficult*	*Easy*	*Nominal*	*Difficult*
# of System Requirements	9	10	1	10	11	2	11	12	1
# of System Interfaces	2	10	3	2	11	4	2	13	5
# of Algorithms	3	9	2	4	10	3	5	11	7
# of Operational Scenarios	4	5	4	2	5	5	4	6	6
Equivalent Total Requirements Size		351.90			402.90			520.40	
Equivalent New Requirements Size		299.58			341.39			437.77	

SELECT COST PARAMETERS FOR SYSTEM OF INTEREST

	Low Value		Likely Value*		High Value	
Requirements Understanding	**VH**	0.60	**N**	1.00	**L**	1.36
Architecture Understanding	**H**	0.81	**N**	1.00	**L**	1.27
Level of Service Requirements	**L**	0.79	**N**	1.00	**N**	1.00
Migration Complexity	**N**	1.00	**N**	1.00	**EH**	1.92
Technology Risk	**L**	0.84	**N**	1.00	**H**	1.32
Documentation	**L**	0.91	**N**	1.00	**VH**	1.28
# and diversity of installations/platforms	**N**	1.00	**N**	1.00	**EH**	1.86
# of recursive levels in the design	**VL**	0.80	**N**	1.00	**H**	1.21
Stakeholder team cohesion	**H**	0.81	**N**	1.00	**VL**	1.50
Personnel/team capability	**H**	0.81	**N**	1.00	**VL**	1.48
Personnel experience/continuity	**VH**	0.67	**N**	1.00	**L**	1.21
Process capability	**VH**	0.77	**N**	1.00	**L**	1.21
Multisite coordination	**VH**	0.80	**N**	1.00	**L**	1.15
Tool support	**H**	0.85	**N**	1.00	**L**	1.16
Composite effort multipliers		**0.05**		**1.00**		**54.58**

Three-point data entry for size and cost drivers.

COSYSMOR Data Entry, Contd.

COSYSMO MODEL PARAMETERS	Low	Likely	High	Nominal *
Equivalent Size, S (=Equivalent New)	318	338	396	341
Unit Effort Constant, A:Baseline	38.550	38.550	38.550	38.55
Unit Effort Constant, A:User**	49.136	49.136	49.136	38.55
Unit Effort Constant, A Selected	49.136	49.136	49.136	38.55
Size Exponent, E	1.000	1.060	1.100	1.06
Cost Parameter Product,D	0.364	1.202	3.752	1.00
SYSTEMS ENGINEERING PERSON MONTHS	**37.4**	**186.6**	**874.7**	**122.9**
SYSTEMS ENGINEERING PERSON HOURS	5679	28361	132952	18675

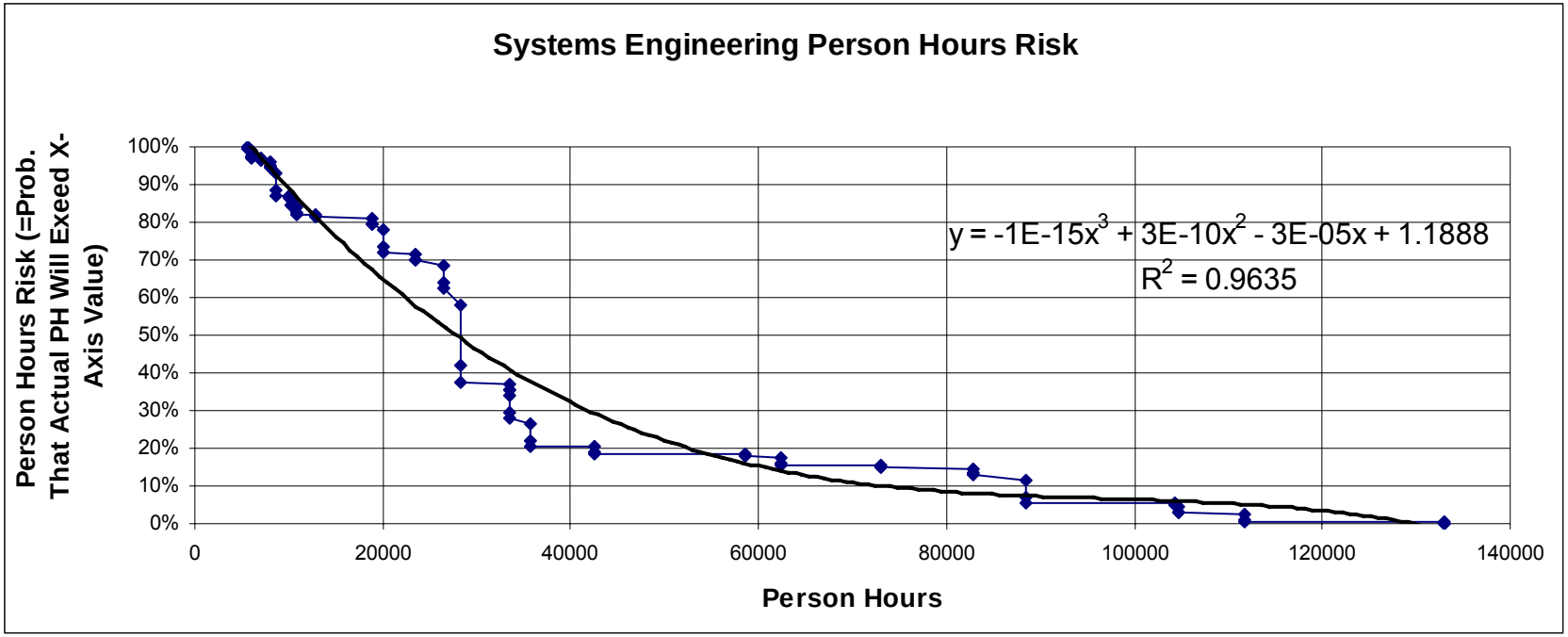
COSYSMO MODEL FORM
PM, PH=A*(S^E)*D
PM=Person Months
PH=Person Hours

Three-point data entry effort (A) and exponent (E) values

COSYSMOR Data Entry, Contd.

New				Modified				Reused				Deleted			
Proportion, p_N				Proportion, p_M				Proportion,p_R				Proportion,p_D			
Calculated	Estimated	Selected	Rel. Cost	Calculated	Estimated	Selected	Rel Cost	Calculated	Estimated	Selected	Rel Cost	Calculated	Estimated	Selected	Rel Cost
74.12%	71.00%	74.12%	100.00%	4.04%	2.00%	4.04%	75.00%	18.46%	25.00%	18.46%	25.00%	3.38%	2.00%	3.38%	50.00%
73.99%	70.00%	73.99%	100.00%	1.68%	5.00%	1.68%	75.00%	22.65%	22.00%	22.65%	25.00%	1.68%	3.00%	1.68%	50.00%
62.00%	51.00%	62.00%	100.00%	3.29%	10.00%	3.29%	75.00%	30.59%	35.00%	30.59%	25.00%	4.13%	4.00%	4.13%	50.00%
83.38%	63.00%	83.38%	100.00%	3.05%	4.00%	3.05%	75.00%	12.16%	31.00%	12.16%	25.00%	1.41%	2.00%	1.41%	50.00%
		Enter X If you want to use REUSE sheet, else leave blank.					x								

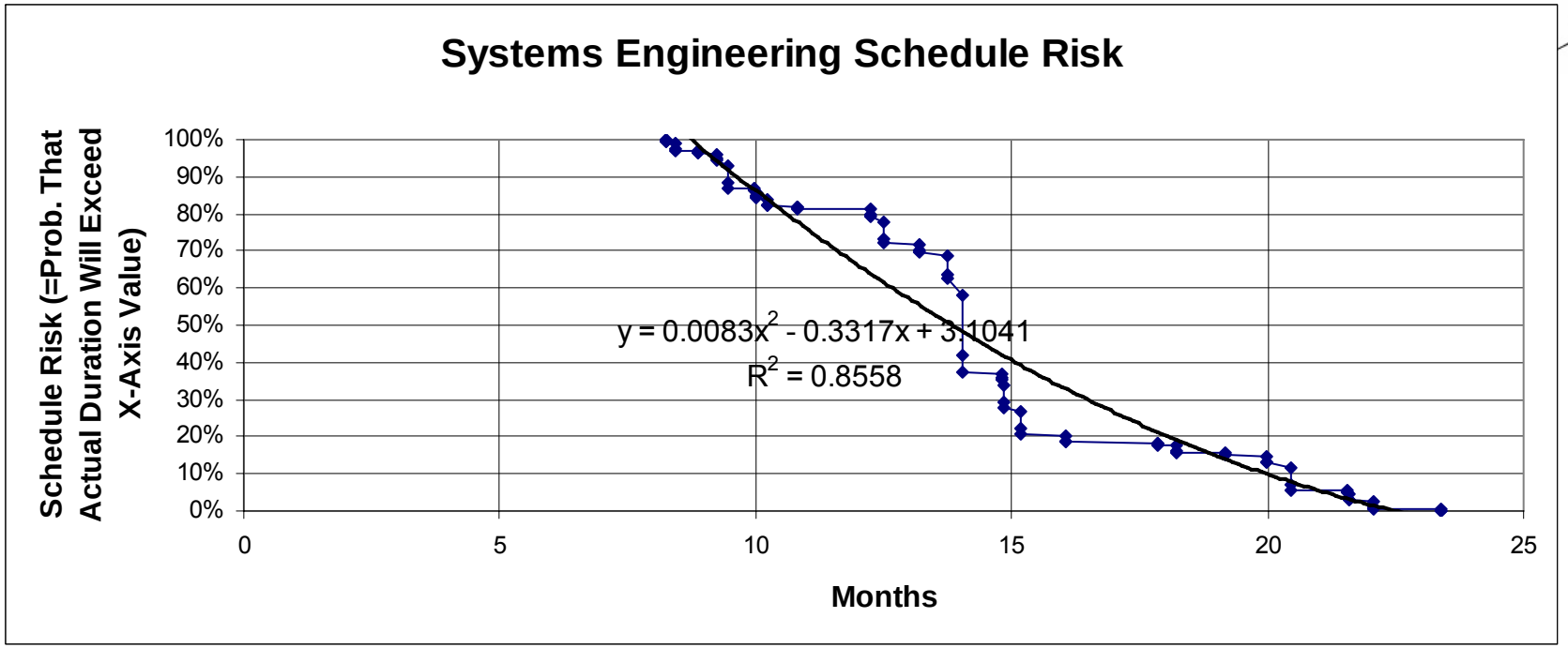
COSYSMOR Outputs



Use This Graph to help understand labor (and cost) exposure for a labor choice (say in a proposal)

Example: The risk of exceeding 6000 labor hours is slightly less than 20%.

Note: You might choose to present only the smooth curve fit rather than the discrete plot.



This plot relates to "ideal" schedule or duration for overall systems engineering Effort. The value for schedule (T) relates to effort (C) using the formula $T=a*(C^b)$. However, the overall duration of se effort is typically established by the overall program, and not by SE.

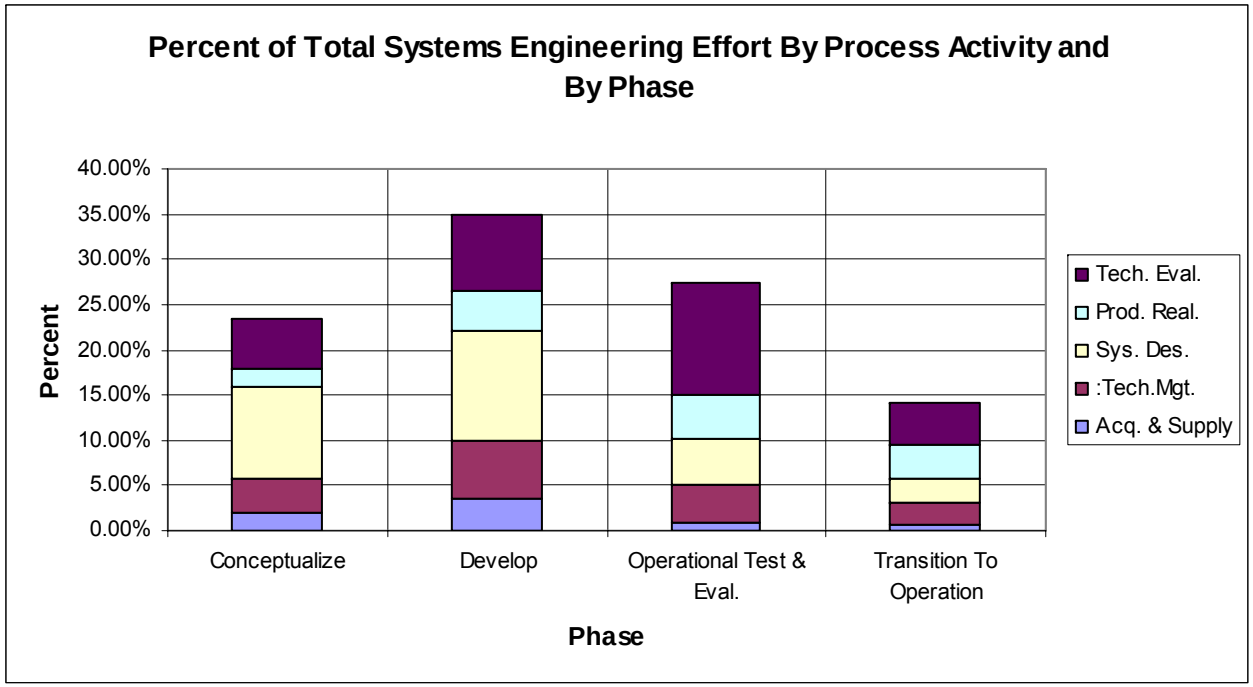
Example: The risk of exceeding 20 months is slightly less than 10%.

Note: You might choose to present only the smooth curve fit rather than the discrete plot

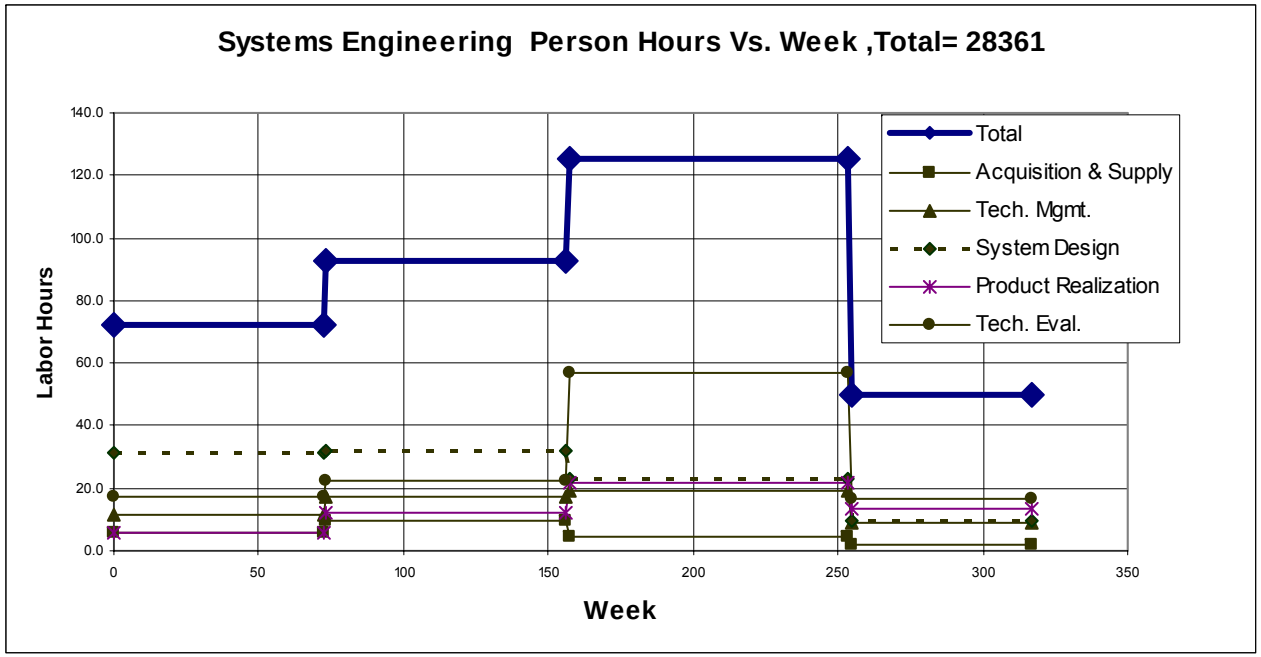
Summary COSYSMOR Person Hours/ Person Months and Schedule Risk/Confidence Statistics

Item	Effort Person Hours	Person Months*	Ideal Schedule **
Minimum =	5679	37.4	8.3
Risk=	99.37%		
Confidence=	0.63%		
Most Likely=	28361	186.6	14.0
Risk=	37.50%		
Confidence=	62.50%		
Maximum =	132952	874.7	23.4
Risk=	0.00%		
Confidence=	100.00%		
20% Risk/ 80% Confidence=	42606	280.3	16.1
30% Risk/ 70% Confidence=	33538	220.6	14.8
50% Risk/ 50% Confidence=	28361	186.6	14.0
95% Risk/5% Confidence =	8024	52.8	9.3
5% Risk/95% Confidence =	104246	685.8	21.6
152	* Person Hours Per Person Month		

This table summarizes the data from the effort risk and the “ideal” schedule risk estimates.

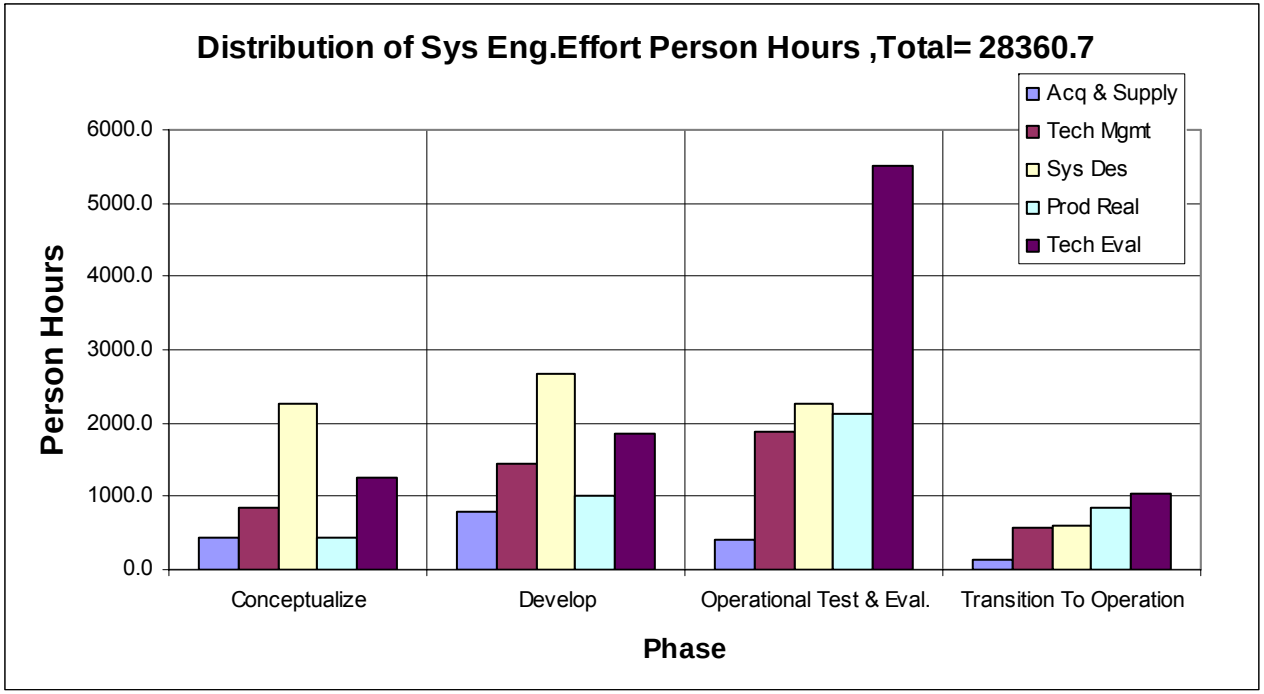


The percentages shown were established by the COSYSMO working group. The COSYSMOR tool treats them as parameters that the user can change, based on his organization's experience.

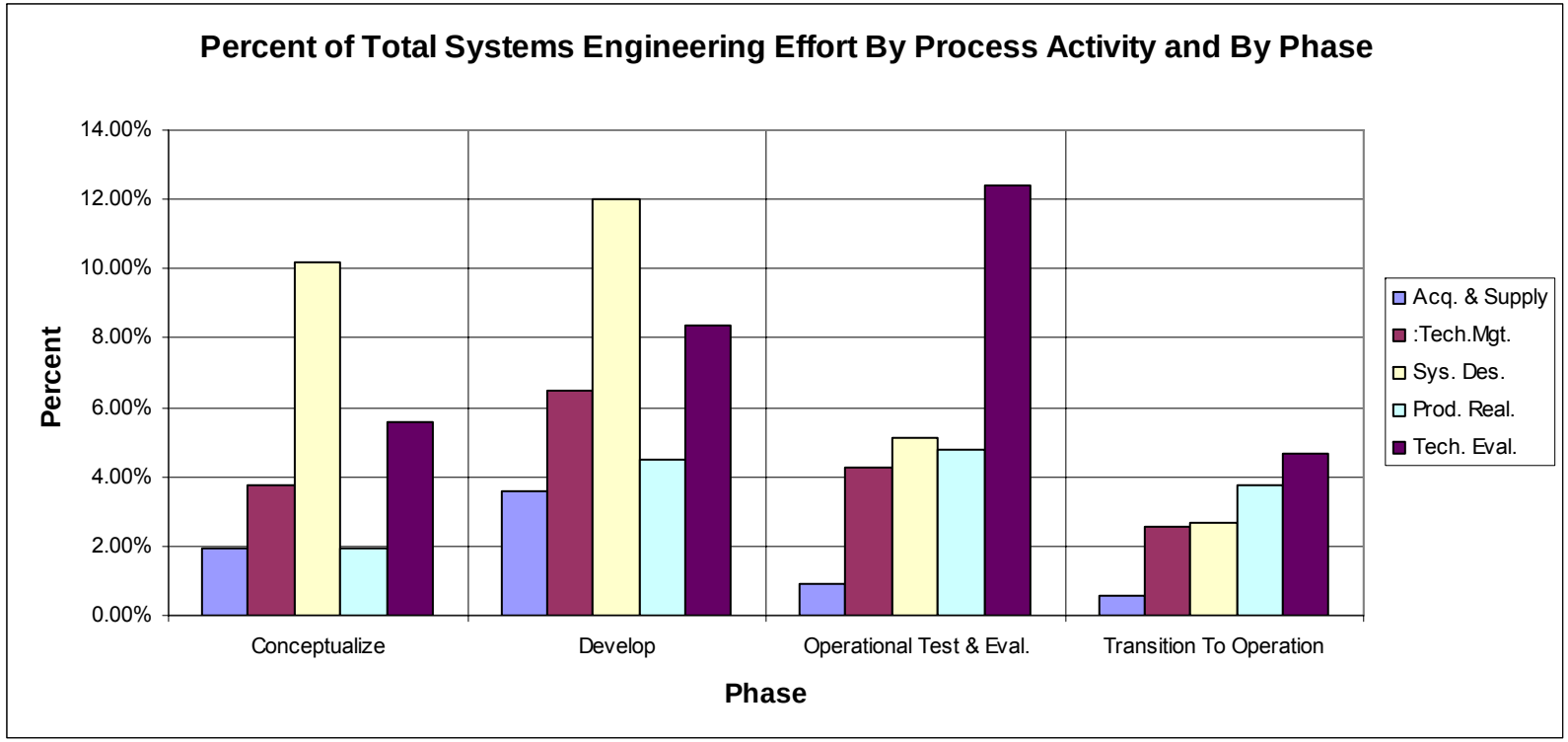


The plot can be given with respect to months. The user enters The week-month relationship, e.g., 4.3 weeks per month.

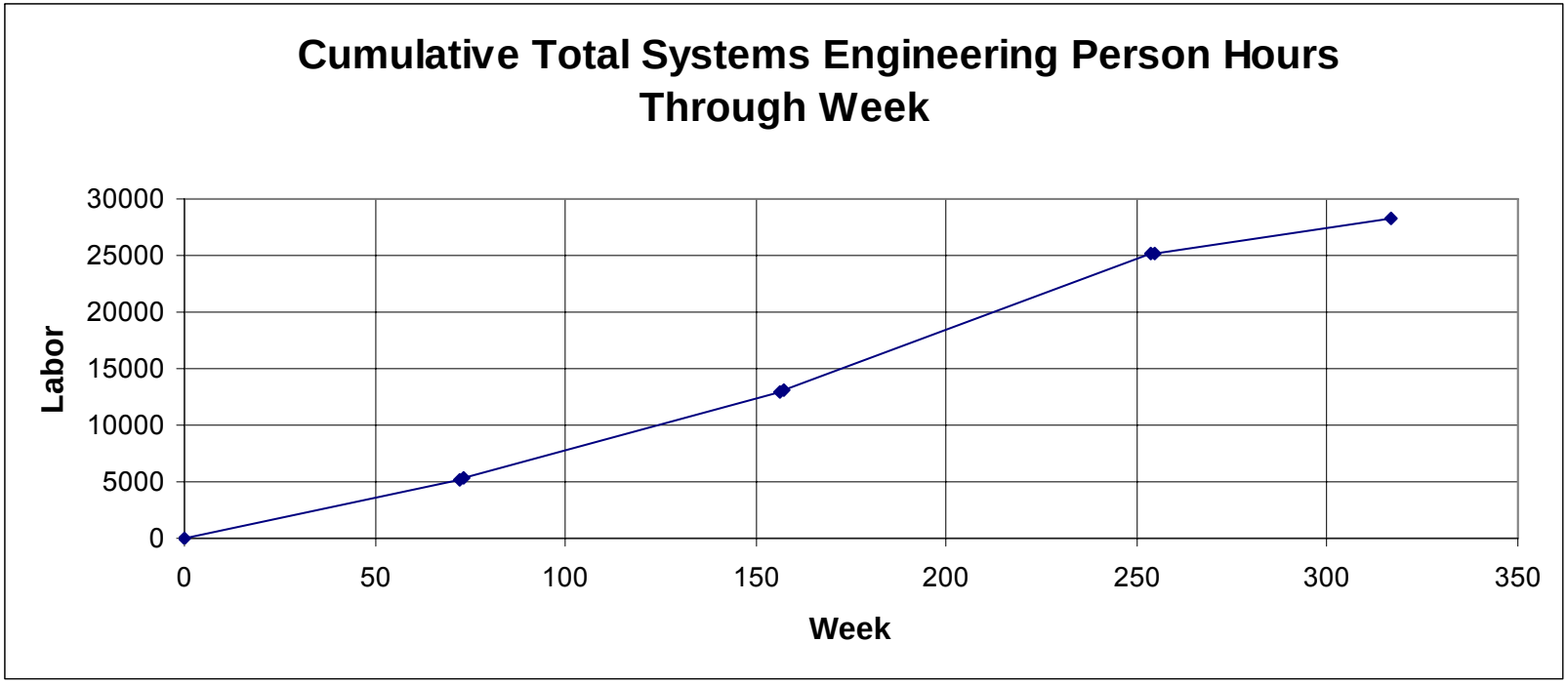
The total person hours can be selected for various risk levels. In this example, it is the 50% risk level.



The total person hours can be selected for various risk levels.
In this example, it is the 50% risk level.



This plot presents the same information as the prior plot except that it is by percent rather than person hours.



The plot can be given with respect to months. The user enters The week-month relationship, e.g., 4.3 weeks per month.

The total person hours can be selected for various risk levels. In this example, it is the 50% risk level.

COSYSMOR Future Features

- Include:
  - Calibration of A & E parameters.
  - Calibration/Estimation Support For Relative Unit Costs of: Reused, Modified, and Deleted Size Drivers.
- Are there others that you might want to be included?

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Backup

Basic or Academic COSYSMO Overview

- The Academic COSYSMO model is implemented on an excel platform that can be used to provide an estimate of the total labor hours for five systems engineering activities or processes over four project development life cycle phases.
  - The five activities are:
    - Acquisition & Supply
    - Technical Management
    - System Design
    - Product Realization
    - Technical Evaluation
  - The four phases are:
    - Conceptualize
    - Develop
    - Operational Test & Evaluation
    - Transition to Operation

Basic or Academic COSYSMO Overview, Contd.

- The fundamental equation implemented by Academic COSYSMO and COSYSMOR is:

  $PH = A*(S^E)*\Pi\ Di$

  where:

  - PH=systems engineering person hours
  - A=unit effort constant
  - S=equivalent size, number of equivalent requirements
  - E=exponent
  - Di, i=1,2,….,14 are the cost driver values
- All of these parameters are considered to be mutually independent.

The COSYSMOR User Enters 3-Value Estimates For:

- Model Parameters A and E
- Scope or Project Size Characteristics, Equivalent Size Drivers:
  - Number of System Requirements
  - Number of System Interfaces
  - Number of System-Specific Algorithms
  - Number of Operational Scenarios
- Cost/Performance Characteristics, Cost Drivers:
  - Requirements Understanding
  - Architecture Understanding
  - Level of Service Requirements
  - Migration Complexity
  - Technology Risk
  - Documentation
  - # and diversity of installations/platforms
  - # of recursive levels in the design
  - Stakeholder team cohesion
  - Personnel/team capability
  - Personnel experience/continuity
  - Process capability
  - Multi-site coordination
  - Tool Support

Concerning Risk Distributions

- COSYSMOR provides “risk” and “confidence” distributions for the labor and schedule or project duration estimates, based three-point values for each of its parameters that the user enters.
- Risk=Prob[actual value >target value]; the complementary cumulative distribution function (CCDF).

  Confidence=100%-Risk%=Prob[actual≥ target value]; the cumulative distribution function (CDF) of the cost.
- Note: these definitions apply to quantities for which “better” is smaller, e.g., effort/cost and project duration. They are reversed for cases in which “better” is larger, such as Mean-Time-Between Failure.
- The COSYSMOR risk assessment capability is implemented using three-point approximations; they are non-parametric, meaning that they are not derived as approximations to any particular distribution such as a Gamma or a Weibull.
  - This in contrast to the use of Monte Carlo methods, in which a particular distribution is used and then a large number of instances are generated from it.
- COSYSMOR does not generate such a large number of instances.
  - Rather, it generates an approximation to the distribution from the 3 point approximations to each variable. For example, if there are 4 (mutually independent) variables, the approximation has 81 values (=3x3x3x3).

Probability Approximation Used In COSYSMOR

- COSYSMOR implements the approximation developed by Keefer and Bodily, the “extended Pearson-Tukey” method.
  - They evaluated 22 approximations, and found this one to be the best in terms of their abilities to estimate the means and variances of various distributions.
- This method approximates a continuous distribution by a discrete one:

Fractile	Probability Assigned
0.05	0.185
0.50	0.630
0.95	0.185