

## **NOSTROMO: Using Monte Carlo Simulation to Model Uncertainty Risk in COCOMO II (U)**

**Pam McDonald**  
THAAD Project Office

**Dan Strickland**  
Dynerics, INC.

**Charles Wildman**  
THAAD Project Office

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## Overview (U)

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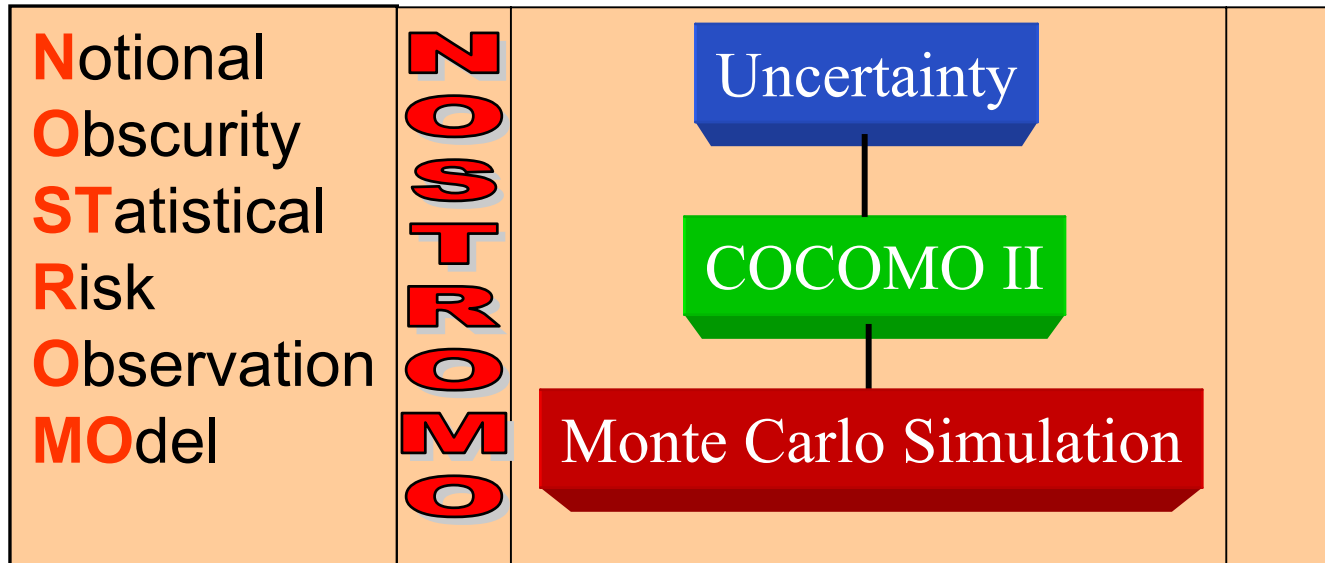
- NOSTROMO Concept
  - Monte Carlo Simulation
  - Uncertainty Levels
  - NOSTROMO Additions
  - NEWT
  - Examples
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## Background (U)

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- There are 31 factors normally associated with a COCOMO II model
  - New and Adapted Size (SLOC)
  - 17 Cost Drivers
  - 5 Scale Factors
  - 3 Adaptation Percentages of Modification
  - 3 Adaptation Cost Drivers
  - Requirements Evolution and Volatility
- With any parametric model there are degrees of uncertainty and subjectivity; some factors are more concrete than others (Process Maturity is more concrete than Complexity)
- Based on the ranges of uncertainty, a Monte Carlo Simulation can model several hundreds/thousands of COCOMO II estimates with varying degrees
- A Monte Carlo Simulation of COCOMO II can produce a range of estimates and the risk factors associated with each estimate
- GOAL – Develop a Monte Carlo Simulation of COCOMO II based on the ranges of uncertainty associated with each factor

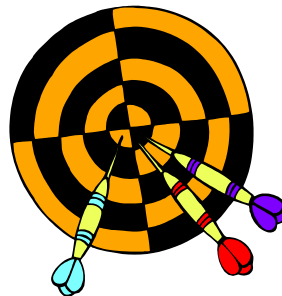
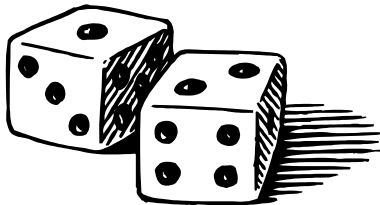
## NOSTROMO Concept (U)



- NOSTROMO first takes normal COCOMO II inputs
- NOSTROMO accounts for uncertainty in the settings
- NOSTROMO uses Monte Carlo to simulate hundreds of COCOMO II estimates using the inputs and uncertainties

## Monte Carlo Simulation (U)

- Monte Carlo use random numbers to simulate or “game” several different possible outcomes to perform large scale “what if” scenarios
- A Monte Carlo simulation will show more stability with more runs
- The basis for Monte Carlo simulations is ranges in values
- NOSTROMO uses the COCOMO II factors, uncertainty values, and Monte Carlo simulation to generate a population of possible values for an estimate
- The Monte Carlo simulation output can be used to generate a population mean, standard deviation, and confidence intervals
- NOSTROMO, like many cost estimation Monte Carlo simulations, is based a boundary set by a low, high, and most likely value



## Defining Uncertainty Levels (U)

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- Level 1 – No Uncertainty – applicable to values that are discrete or validated over long periods of development and observation (CMM Level 3 = HI Process Maturity)
  - Level 2 – Low Uncertainty – applicable to values that are validated over short periods of time with a possibility of some change (Database Size Cost Driver)
  - Level 3 – Medium Uncertainty – applicable to values with some uncertainty or subject to outside change (Analyst Experience)
  - Level 4 – High Uncertainty – applicable to values with a high degree of disparity in opinion or subject to a high degree of outside change (Product Complexity Cost Driver)
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## Distributions of Uncertainty (U)

NOSTROMO assumes ceiling and floor limits of the highest and lowest default values for each COCOMO II Scale Factor and Cost Driver

Level 1 - Certain

Level 2 - Low Uncertainty - Normal

Level 3 - Medium Uncertainty - Triangle

Level 4 - High Uncertainty - Uniform

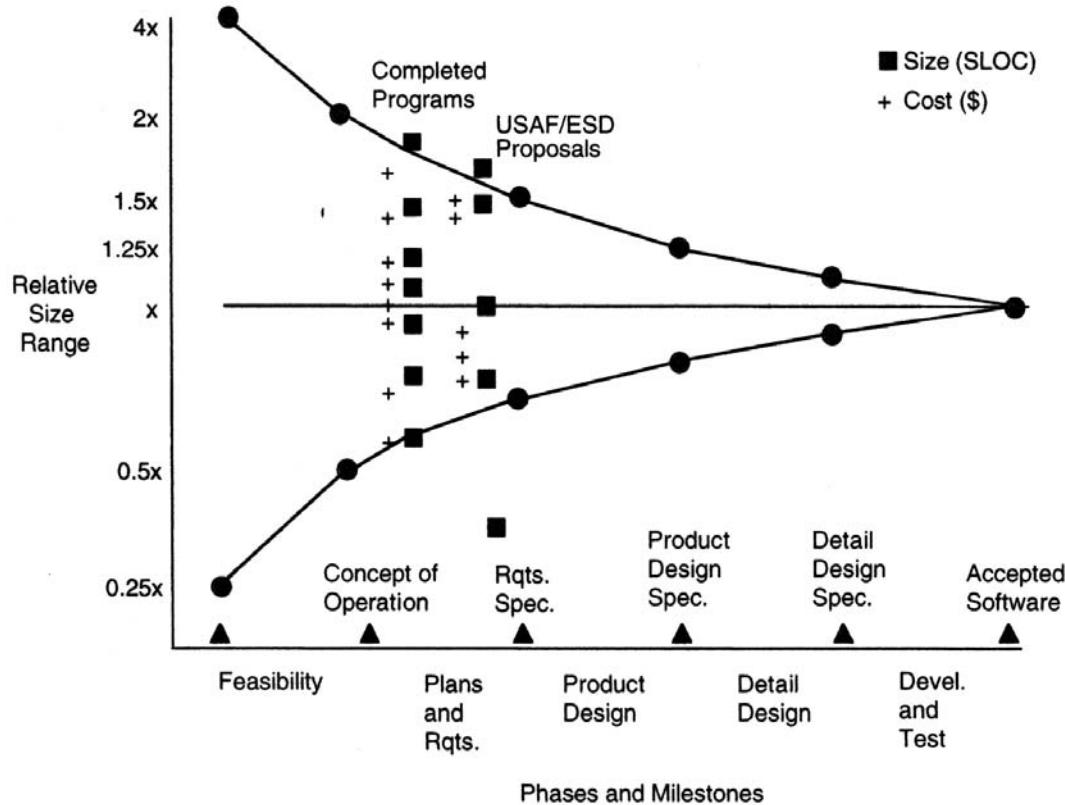
Setting  $n-1$

Setting  $n$

Setting  $n+1$

NOSTROMO changes the distribution and sets the high and low points based on the level of uncertainty with each factor

## Software Cost and Size Accuracy Vs. Phase (U)



Phase	Low	High
Feasibility	0.25x	4x
Concept of Operation	0.5x	2x
Requirements Specification	0.667x	1.5x
Product Design Specification	0.8x	1.25x
Detail Design Specification	0.91x	1.1x
Development and Test	x	x

Instead of uncertainty, NOSTROMO uses phase of development to range size estimates (New and Adapted) based on the Boehm "horn chart"

[Reference - SOFTWARE COST ESTIMATION WITH COCOMO II (P 10) - BOEHM 2000]

## NOSTROMO Application (U)

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- Microsoft Excel 2002 worksheet with attached macros and Visual Basic code
  - Currently on version 0.3.7 (as of 10/3/04)
  - Does not use outside applications for Monte Carlo simulation (standard random number generation from Visual basic)
  - Limited testing performed on a proof-of-concept application
  - Suggest limiting Monte Carlo run size to 500-2000 runs
- Generates two pages of output – Data and Charts
  - Data page contains all outputs from Monte Carlo simulation, charting data, and histograms
  - Charts page contains Confidence Intervals for output of COCOMO II and Putnam models, charts, and histograms
  - NOSTROMO – Data Sheet and CM Control Sheet are Developer pages and should **not** be removed
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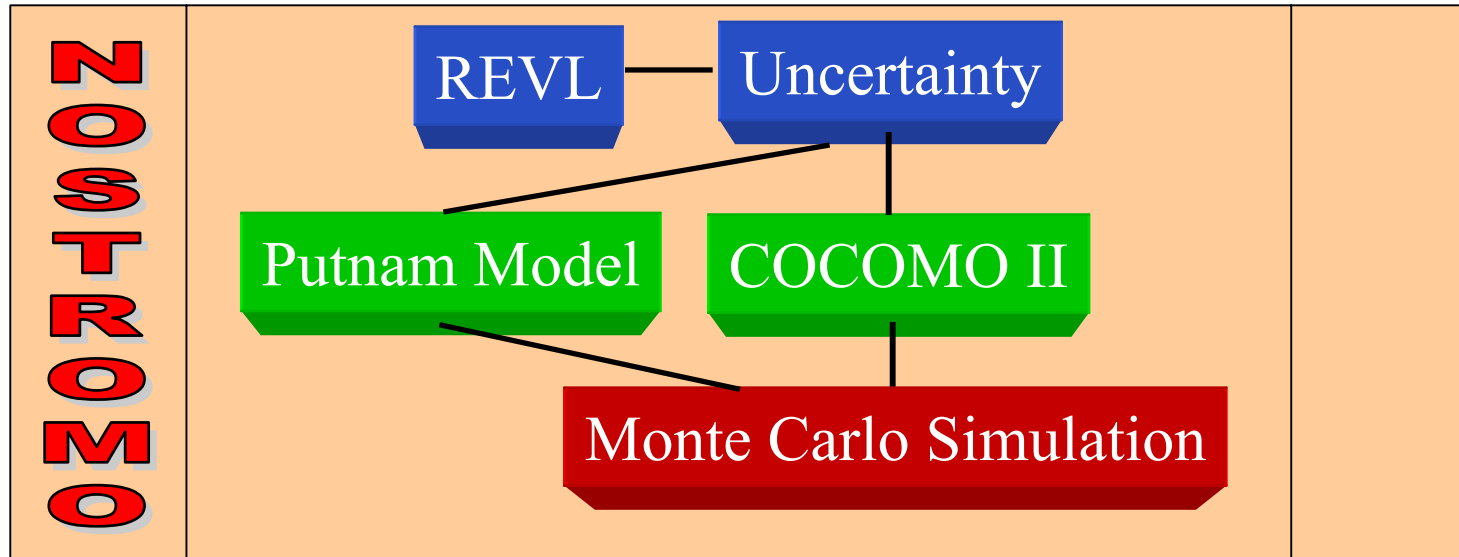
## **NOSTROMO Application Version History (U)**

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<b>Version</b>	<b>Date</b>	<b>Functionality</b>
v.0.1	2/17/2003	Concept demonstration, no VB code, high storage and memory constraints
v.0.2.1	2/19/2003	Added VB code to dynamically create tables
v.0.2.2	3/2/2003	Added scale factors and cost drivers
v.0.2.3	4/8/2003	Added adapted code and reuse variables
v.0.3	4/14/2003	Added Uncertainty Estimator Worksheet
v.0.3.1	5/21/2003	Added SLOC output and changed name to NOSTROMO
v.0.3.2	6/9/2003	Added SLOC vs. Effort graph, Duration vs. Effort, notation for mean
v.0.3.3	6/18/2003	Added REVL effect
v.0.3.4	7/12/2003	Added Productivity Estimate
v.0.3.5	8/1/2003	Added Requirements Analysis, Productivity, Output Screen
v.0.3.6	10/1/2003	Added Putnam data and reports; SLOC estimate by phase
v 0.3.7	10/3/2003	Histogram charts added; removed reqs from effort equation

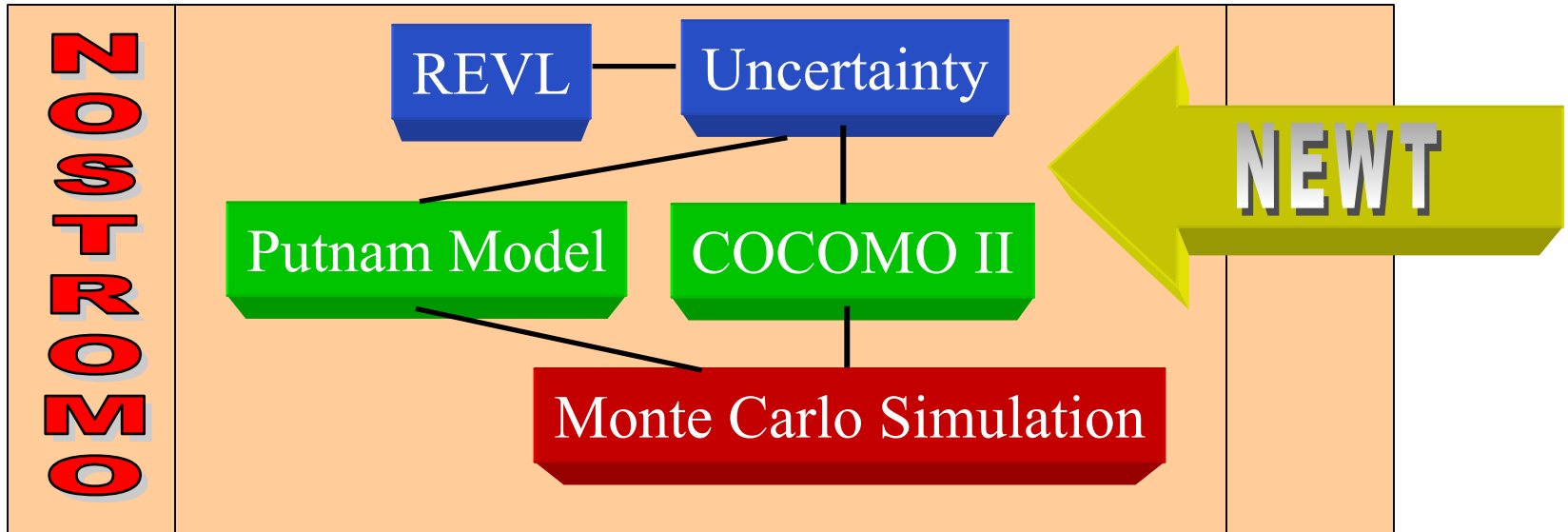
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## NOSTROMO Additions (U)



- NOSTROMO uses the ESLOC estimate from the COCOMO II model with the Putnam Productivity parameter (with uncertainty) to generate an alternate estimate (Putnam, Myers 1992)
- NOSTROMO uses the default Requirements Evolution and Volatility (REVL) settings detailed by Strickland and McDonald

## NOSTROMO Additions – NEWT (U)



- NOSTROMO Entry Writing Tool (NEWT) is an optional worksheet that collects survey (Delphi) results for cost drivers and scale factors
- Based on the deviation of the entries, NEWT selects a consensus value and assigns an uncertainty value for each entry
- NEWT results can be copied directly to the NOSTROMO Main Sheet

# Screenshots – NOSTROMO Input Sheet – Notional Data (U)

The screenshot displays a software input sheet with various fields and buttons. Red callout boxes point to specific elements:

- Software Item Name:** Points to the 'SI Name' field, which contains 'Sample'.
- Scale Factors:** Points to the 'Input' column of the first table.
- Code Size:** Points to 'NEW CODE', 'REVL', 'ADAPTED CODE', '% DESIGN MOD', '% CODE MOD', and '% TEST MOD'.
- Cost Drivers:** Points to 'TIME', 'STOR', 'PVOL', 'RELY', 'DATA', 'CPLX', 'RUSE', and 'DOCU'.
- Iterations:** Points to 'TOOL', 'SITE', and 'SCED'.
- Putnam Productivity:** Points to 'Number of Iterations' and 'Putnam Technology Rating'.
- Runs Monte Carlo With Current Settings:** Points to the 'Run SI' button.
- Clears the Screen For Data Entry:** Points to the 'ClearScreen' button.

SI Name	Sample		
Input	Rating	Uncertainty	UncVal
PREC	LO	Low Uncertainty	2
FLEX	NM	Certain	1
RESL	HI	Medium Uncertainty	3
TEAM	NM	Certain	1
PMAT	HI	Medium Uncertainty	3
NEW CODE	50000	Product Design Spec.	4
REVL	LO	Low Uncertainty	2
ADAPTED CODE	10000	Product Design Spec.	4
% DESIGN MOD	5%	Medium Uncertainty	3
% CODE MOD	5%	Certain	1
% TEST MOD	10%	Certain	1
Assessment and Adaptation	4%	Certain	1
Software Understanding	NM	Certain	1
Unfamiliarity with Software	0.4	Certain	1
TIME	VH	Certain	1
STOR	NM	Low Uncertainty	2
PVOL	HI	Certain	1
RELY	HI	Certain	1
DATA	NM	Medium Uncertainty	3
CPLX	HI	Low Uncertainty	2
RUSE	NM	Certain	1
DOCU	VL	Certain	1
ACAP	HI	Certain	1
APEX	HI	Low Uncertainty	2
PCAP	NM	Certain	1
PLEX	NM	High Uncertainty	4
LTEX	NM	Certain	1
PCON	HI	Medium Uncertainty	3
TOOL	NM	Low Uncertainty	2
SITE	VH	Medium Uncertainty	3
SCED	NM	Medium Uncertainty	1
Number of Iterations	1500		
Putnam Technology Rating	4181	Low Uncertainty	2

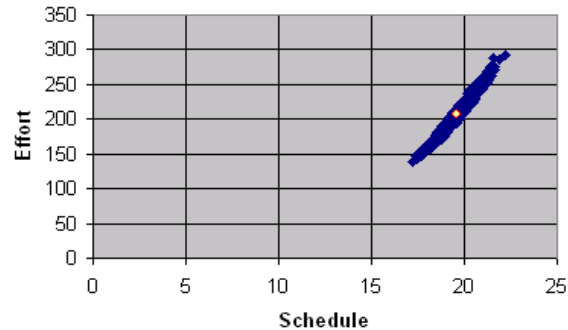
Buttons: Run SI, ClearScreen



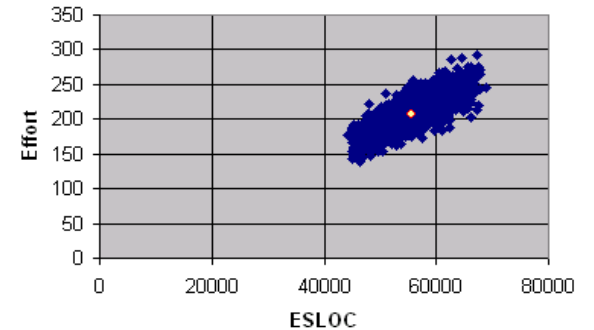
# Screenshots – NOSTROMO COCOMO II Charts Sheet – Notional Data (U)

Percentile	Effort	Schedule	Size	Productivity
99%	266.19	21.45	66995	251.68
95%	249.06	20.91	63669	255.64
90%	239.92	20.63	61896	257.98
80%	228.86	20.28	59749	261.07
70%	220.89	20.03	58201	263.49
60%	214.07	19.82	56878	265.70
50%	207.70	19.62	55642	267.89
40%	201.33	19.42	54405	270.22
30%	194.52	19.21	53082	272.89
20%	186.54	18.96	51534	276.26
10%	175.48	18.62	49387	281.43
5%	166.35	18.33	47614	286.23
1%	149.22	17.80	44288	296.80

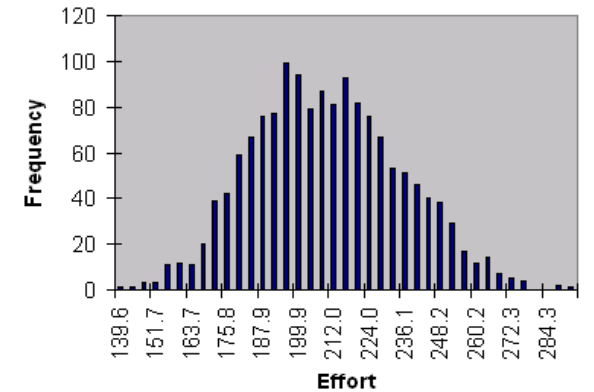
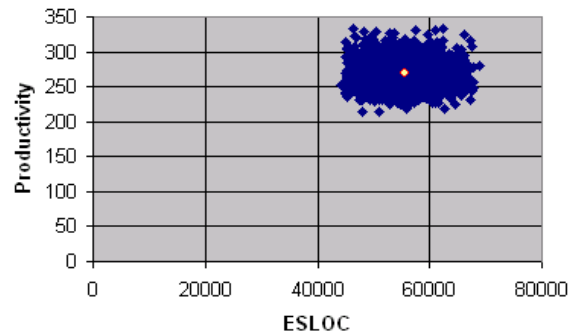
Sample\_Data - Duration vs. Effort



Sample\_Data - ESLOC vs. Effort

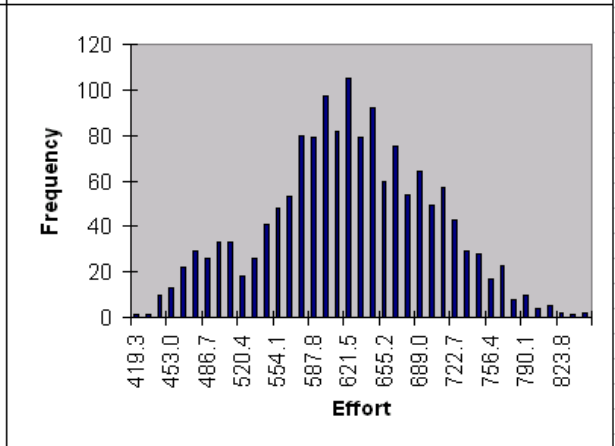
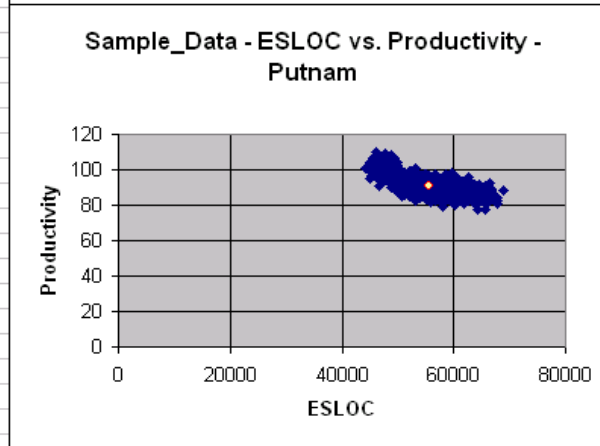
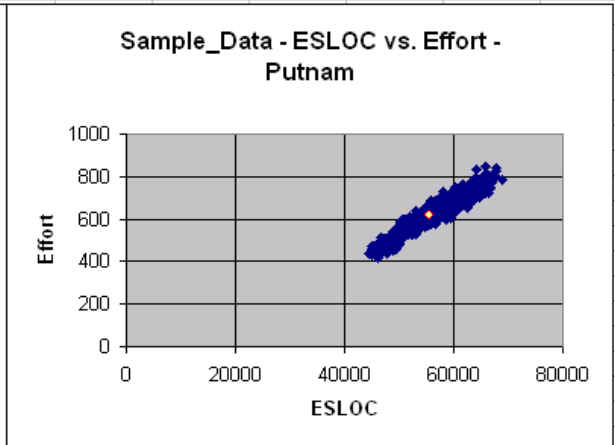
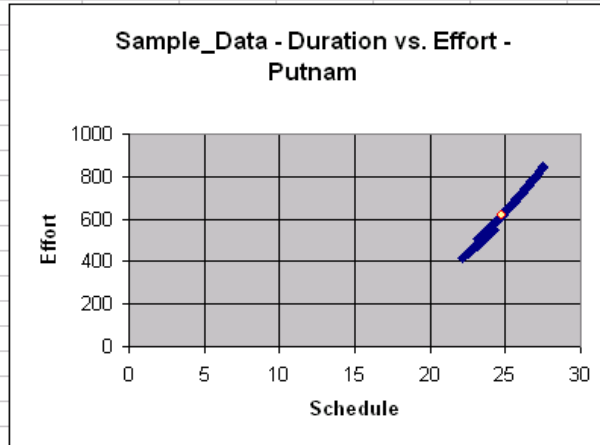


Sample\_Data - ESLOC vs. Productivity



# Screenshots – NOSTROMO Putnam Charts Sheet – Notional Data (U)

Putnam Percentile	Effort	Schedule	Size	Productivity
99%	799.01	27.03	66995	83.85
95%	745.51	26.37	63669	85.40
90%	716.99	26.01	61896	86.33
80%	682.45	25.58	59749	87.55
70%	657.55	25.28	58201	88.51
60%	636.27	25.01	56878	89.39
50%	616.38	24.76	55642	90.27
40%	596.49	24.52	54405	91.21
30%	575.21	24.25	53082	92.28
20%	550.30	23.94	51534	93.65
10%	515.76	23.51	49387	95.76
5%	487.24	23.16	47614	97.72
1%	433.74	22.49	44288	102.11



## Using NOSTROMO (U)

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- Initial Estimates
    - Use NEWT and a survey technique to identify driver settings and uncertainty
    - Run NOSTROMO with size and phase inputs to get a range of results
    - Select results based on business criteria
  - “What-If” Scenarios
    - Isolate cost drivers and scale factors in question by setting Uncertainty Level > 1
    - Set non-factors to Uncertainty Level = 1
    - Run NOSTROMO with size and phase inputs
  - Model Validation
    - Input current model settings as first entry in NEWT
    - Poll for additional entries based on survey techniques
    - Run NOSTROMO with size and phase inputs to get a range of results
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## Conclusion (U)

- NOSTROMO empowers cost estimators to account for uncertainty and associated risk in modeling
- NEWT collects survey-type entries and develops NOSTROMO inputs for environment and Uncertainty Level
- Monte Carlo techniques allow NOSTROMO to deliver a range of possible values based on the Uncertainty Levels of the environment modeled

*NOSTROMO delivers insight into the risks associated with software development*

## Sources (U)

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- Bailey, John “Using Monte Carlo and COCOMO-2 to Model a Large IT System Development” COCOMO/SCM 17 October 2002
  - Boehm, Barry *Software Engineering Economics* Prentice-Hall, Inc. Upper Saddle River, NJ 07458 1981
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  - Hesse, Rick “Triangle Distribution: Mathematica Link for Excel” *Decision Line* May 2000
  - Menzies, Sinsel, and Kurtz “Learning to Reduce Risks with COCOMO-II” <http://menzies.us/pdf/00wise.pdf> 2000
  - Putnam, Lawrence H. and Ware Myers *Measures For Excellence: Reliable Software On Time, Within Budget* Prentice-Hall, Inc. Upper Saddle River, NJ 07458 1992
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