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DEFINING THE FUTURE

Logarithms Can Be Your Friends

Controlling Peer Review Costs

November 16, 2005

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Chief Statistician
Northrop Grumman Corporation

Topics

- Business Objectives
- CMMI Requirements for Sub-process Control
- Why Peer Reviews?
- Data Characteristics and Difficulties
- Log-Return Model / Log-Cost Model
- The Lognormal Distribution
- Our Code Walkthrough Data on Logs
- Expanding the Capability
- Summary

Enhancing Joint STARS Capabilities

ISO / TickIT


CERTIFICATE OF APPROVAL

This is to certify that the Quality Management System of:

Northrop Grumman AGS & BMS
Melbourne, Florida, USA

has been approved by Lloyd's Register Quality Assurance
to the following Quality Management System Standards:

ISO 9001:2000

The Quality Management System is applicable to:

The Integration of Large, Complex Airborne Ground Surveillance and Battle Management Systems. This includes Systems and Software Design, Development, Integration, Production, Aircraft Modification and Refurbishment, Delivery and Post Delivery Services, All in Accordance with TickIT.

This certificate is valid only in association with the certificate schedule bearing the same number on which the locations applicable to this approval are listed.

Approval
Certificate No: LRQA 0110692

Original Approval: August 14, 1998
Current Certificate: September 1, 2004
Certificate Expiry: August 31, 2007

Issued by LRQA, Inc. Houston

This document is subject to the provision on the reverse

LLOYD'S REGISTER QUALITY ASSURANCE


The Process Company, LLC

On April 8, 2005,
The Process Company, LLC Completed a
SCAMPI Class A Appraisal
in Accordance with the Software Engineering Institute's Appraisal Framework
using the SE/SW CMMI® version 1.1 and determined that
Northrop Grumman AGS and BMS
met the goals of
SEI Level 5 Process Maturity

Andreas R. Felschow
SEI Authorized Lead Appraiser
The Process Company, LLC

Kevin M. Cotherman
SEI Authorized Lead Appraiser
The Process Company, LLC

CMMI L5

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CMMI Higher Levels – Differences in Behavior

At Level 3…..

- **Management Reacts**
  - Comparative Rather Than Statistical Analysis
  - Process Capability Not Understood
- Measurement Program
  - Data Available for Analysis
  - Analysis at Project Level
  - Data Quality Often Still a Concern

At Level 4…..

- **Management Anticipates**
  - Predicting Results of Critical Processes
  - Evaluating Outcomes Relative to Capability
- Measurement Program
  - Data Relied on for Decision-making
  - Data Analyzed at Organization and Project Levels

At Level 5…..

- **Management Performs "Pre-emptive Strikes"**
  - Identifying & Removing Systemic Process Issues
  - Predicting Results of Innovative Improvements
- Measurement Program
  - Data Relied on for Cost/Benefit Analysis
  - Benefits Forecasted for Technology or Process Optimization

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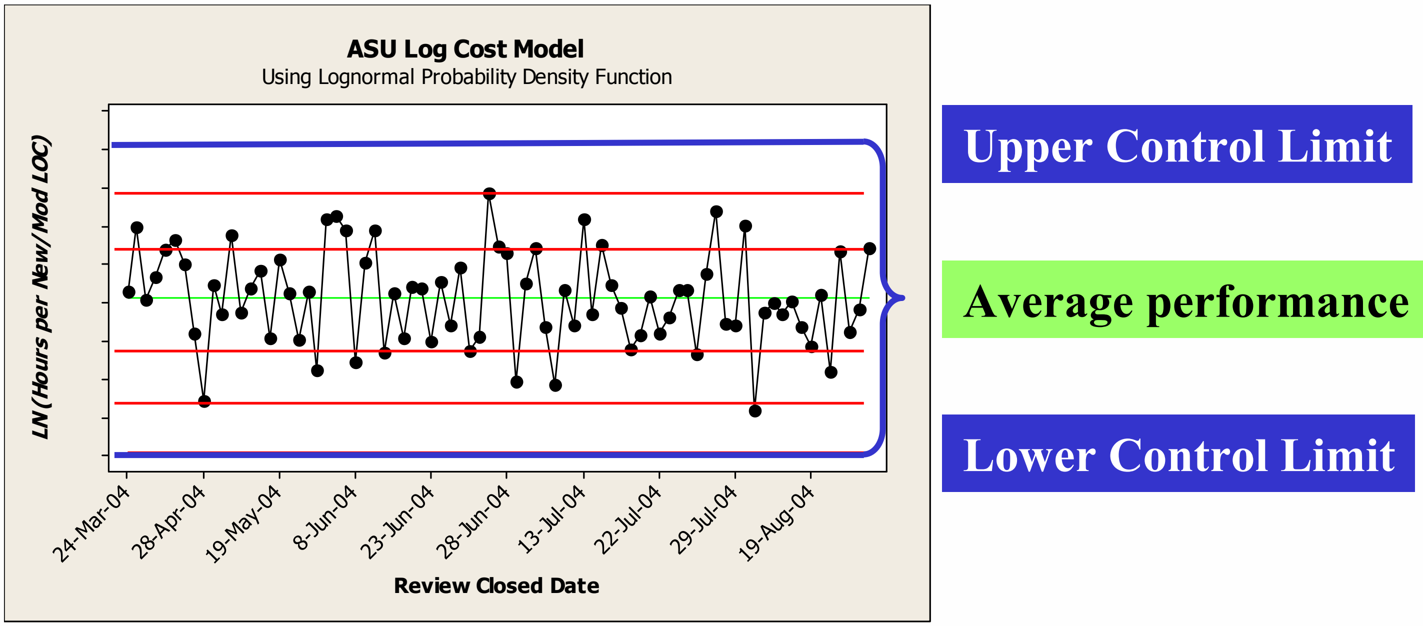
Quantitative Management

CMMI Level 4

- **Establish an Organizational Baseline and Models of Process Performance**
  - Average Performance (Effort, Duration, Quality, …)
  - Range of Performance Variation
  - Contribution of Sub-process Performance to Higher Level Processes
- **Manage Project To Achieve Quantitative Process Performance Goals**
  - Establish Project Goals Based on Organizational Performance
  - Select Sub-processes To Quantitatively Manage
  - Demonstrate Quantitative Control
  - Identify and Correct Special Causes of Performance Variation
  - Feed Data Back to the Organization

Voice of the Process

Quantitative Sub-Process Management



- **A Stable Process**
  - Operates Within the Control Limits 99.7% of the Time
  - Meets Budget
  - Offers Opportunities for Systematic Process Improvement

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Why Peer Reviews?

- **Ubiquity**
  - Many Work Products Reviewed Throughout Software Development Life Cycle
    - Design Artifacts
    - Code
    - Test Plan, Procedures & Reports
- **Frequency**
  - High Data Rates
- **Influence**
  - Approximately 10% of the Software Development Effort Is Spent on Peer Reviews and Inspections
  - Code Walkthroughs Represent Biggest Opportunity

Prior State

SW-CMM Level 4

- **Software Development Baseline Characterized by Life Cycle Phase**
  - SW Requirements-Design-Code & Verification-SW Integration-System Test
  - 10+ Year Process Improvement Record Resulted in Costs Reduced by Over 67%
- **Lower Level Elements Tracked and Managed with Earned Value System**
- **No "Above the Shop Floor" Experience with Statistical Sub-process Control**
- **Issues with Peer Review Quality**
  - Inconsistent Data
  - Superficial Results

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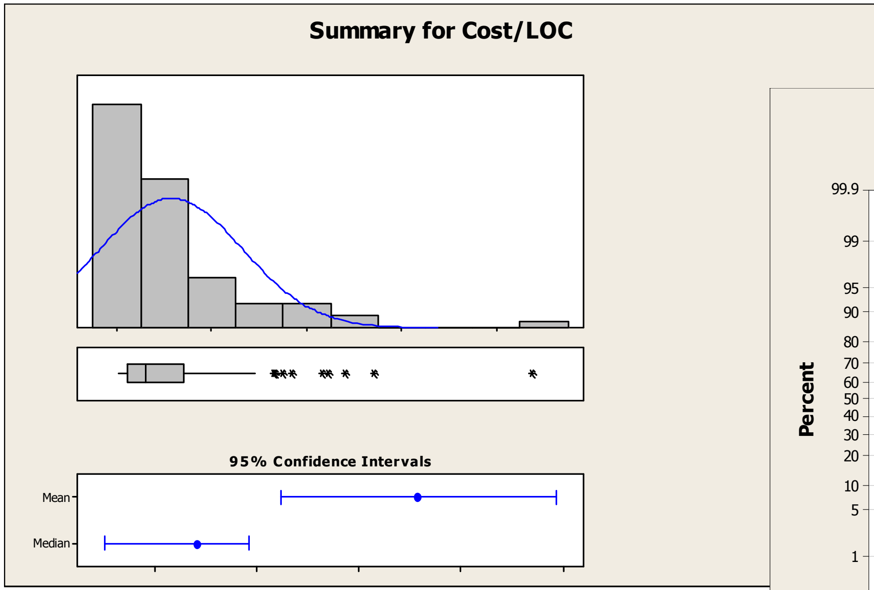
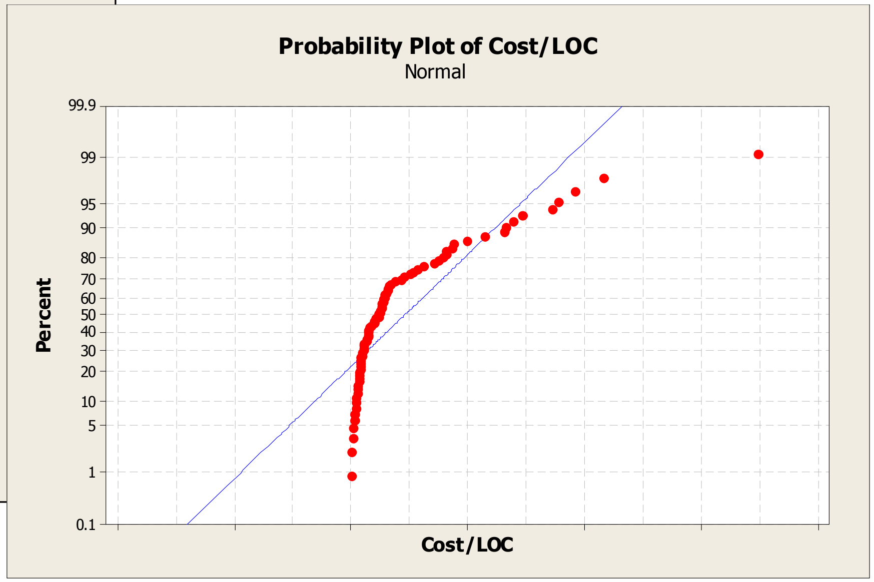
Data Characteristics

Raw Data





Andersen-Darling Test $p < 0.005$

Data Non-normality Violates Probability Model

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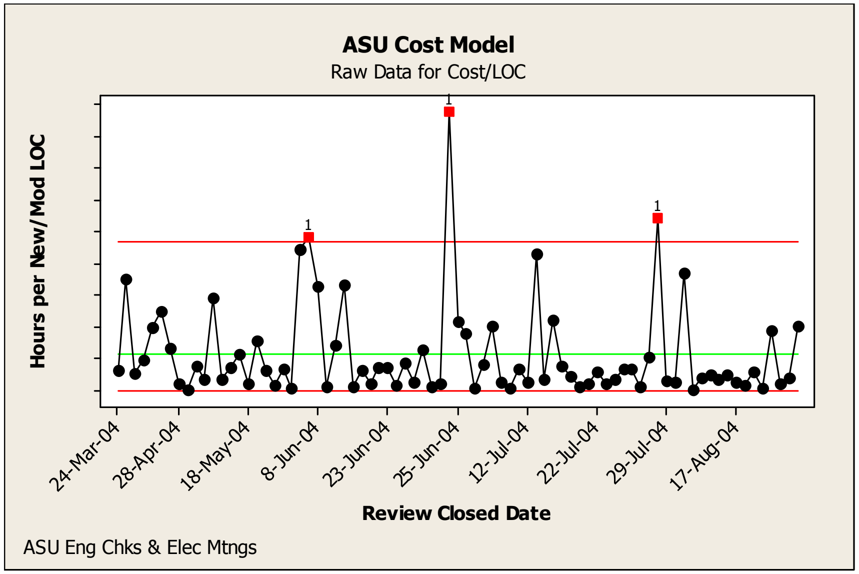
Can Code Walkthroughs Be Controlled?



- **Difficulties**
  - 11% False Alarm Rate (Chebyshev's Inequality)
    - *Penalizes Due Diligence in Reviewing Code*
  - No Meaningful Lower Control Limit
    - *Does Not Flag Superficial Reviews*
  - Arithmetic Mean Distorts the Central Tendency
    - *Apparent Cost Will Not Meet Budget*

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Log-Return Model

Stock Sales

- Consider a stock sale in terms of the number of shares sold for a certain price
- The natural logarithm of the difference between the current and the next per share sale price is normally distributed with zero mean and a constant standard deviation
- Cost basis
  - $s per Share Stock Price

Log-Cost Model

Peer Reviews

- Consider a code walkthrough in terms of the number of lines of code reviewed in a certain number of hours
- By analogy, the natural logarithm of the difference in cost between the current and the next peer review will be normally distributed with zero mean and a constant standard deviation
- Cost Basis
  - Hours per Line of Code Reviewed

Consequences

Log-Return Model

Stock Sales

- Stock prices themselves are lognormally distributed
- The natural logarithms of stock prices follow a normal distribution
- Thus, the log-return data meet the assumptions needed for successful control charting

Log-Cost Model

Peer Reviews

- Peer review costs are lognormally distributed
- The natural logarithms of the peer review costs follow a normal distribution
- Thus, the log-cost data meet the assumptions needed for successful control charting

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Math Details

- **Consider a stochastic process . . ., X_{-2}, X_{-1}, X_0, X_1, X_2, . . . that represents an asset price recorded over time, like a daily sequence of prices for shares of a stock or other commodity**
- **We assume at time t that the realization x_t of X_t is known, but the realization x_{t+1} of X_{t+1} is unknown**
- **The single-period log-return, $ln(X_{t+1}/x_t)$, is random and assumed to be normally distributed, at the given time t**
- **Under these assumptions, X_{t+1}/x_t is a lognormally distributed random variable, and therefore, so is X_{t+1}**

Math Details extracted from:
http://www.riskglossary.com/articles/lognormal_distribution.htm

Salient Properties of the Model

- **When log-returns are normally distributed, the corresponding prices are lognormally distributed**
  - This model “is one of the most ubiquitous models in finance”
- **The distribution of log-returns and share prices have been validated empirically by many market studies accessible on the web**
- **For short time periods in a stable market, the mean return is 0**

Quotation from:
http://www.riskglossary.com/articles/lognormal_distribution.htm

Lognormal Density Function

$$f(x) = \begin{cases} \dfrac{\exp\left(-\dfrac{1}{2}\left(\dfrac{\ln(x)-\mu}{\sigma}\right)^2\right)}{x\sigma\sqrt{2\pi}} & x > 0 \\ 0 & x \le 0 \end{cases}$$

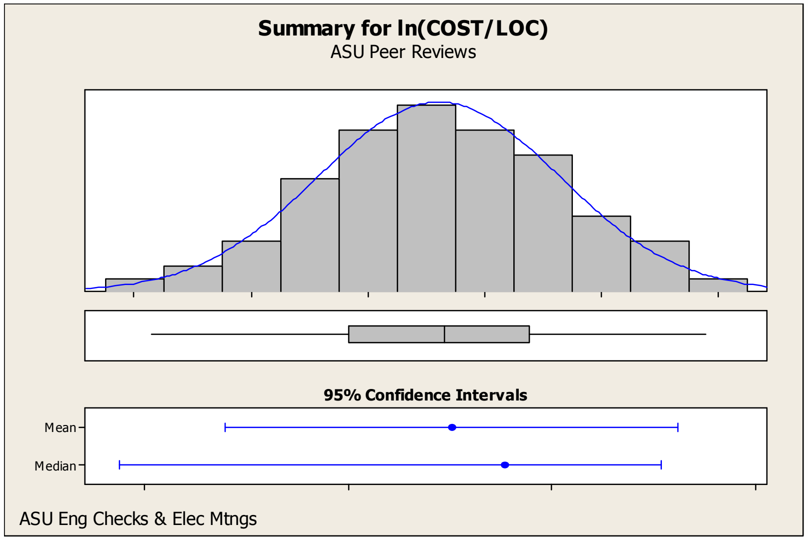
$$X \sim \Lambda[\mu,\sigma^2] \qquad Y = \ln(X) \sim N[\mu,\sigma^2]$$

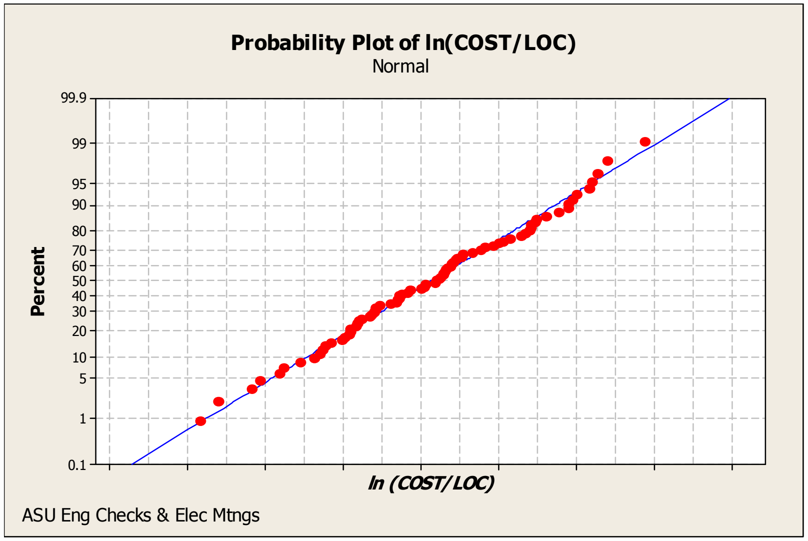
$$E(X) = \exp(\mu + \sigma^2/2)$$

$$Var(X) = \left(\exp(\sigma^2)-1\right)\exp(2\mu+\sigma^2)$$

Math details can be found in any standard mathematical statistics reference, see for example, http://en.wikipedia.org/wiki/Lognormal_distribution.

Our Data on Logs

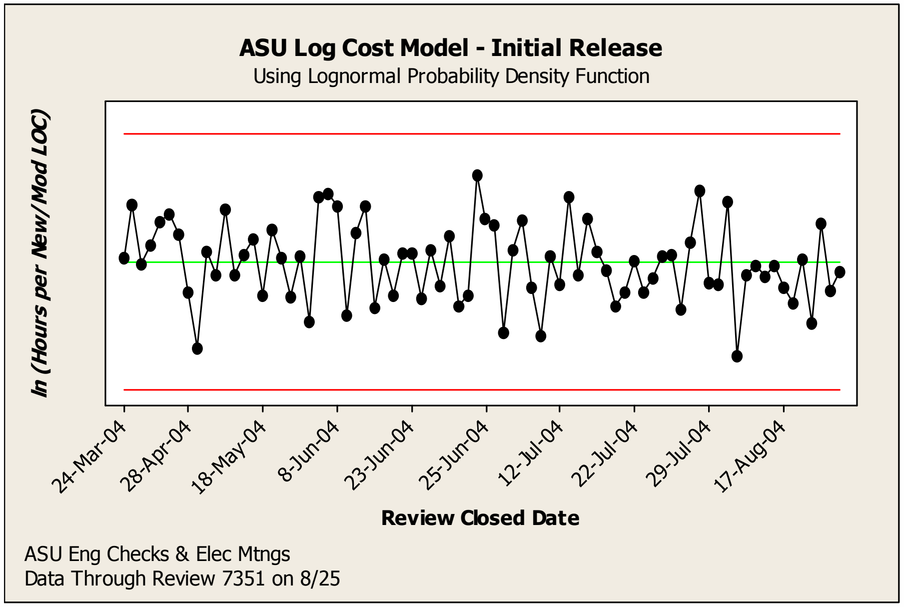




Andersen-Darling Test $p < 0.759$

A Textbook Demonstration

The Transformed Control Chart



- **Impacts**
  - False Alarms Minimized
  - Meaningful Lower Control Limit
  - Geometric Mean Preserves the Budget
    - *OK, You Still Have to Find the Antilog*

An In-control, Stable Process

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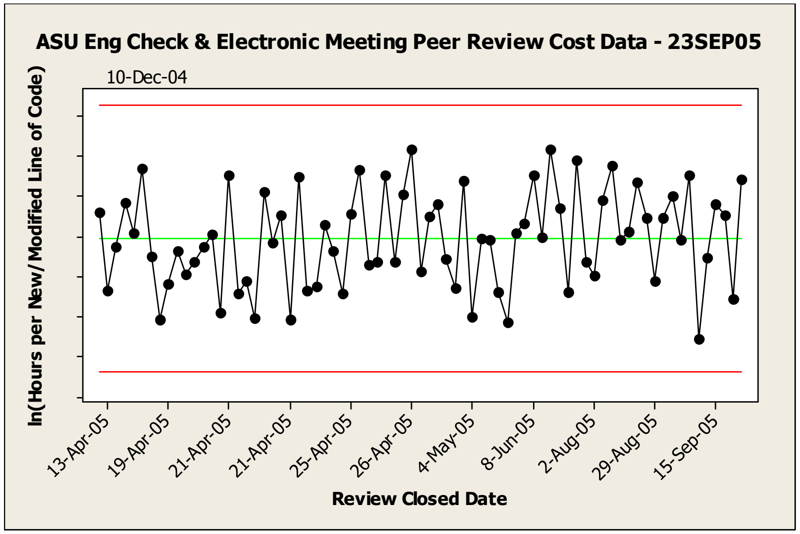
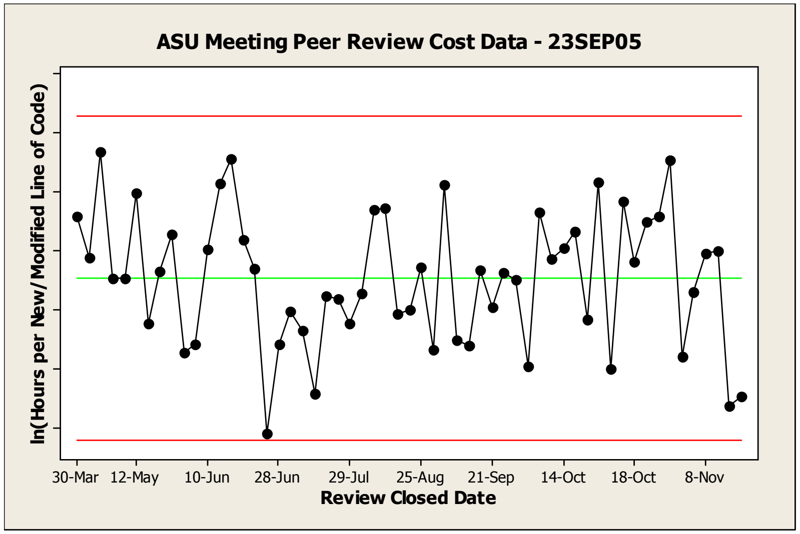
One Year Later . . .

- **Independent Lead Appraisers Cited Innovation and Novelty of Log-cost Model in Level 4 (10/2004) and Level 5 (4/2005) Appraisals**





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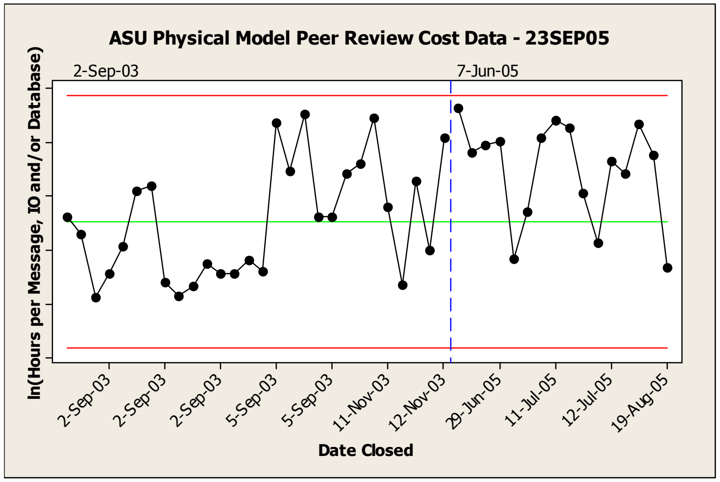
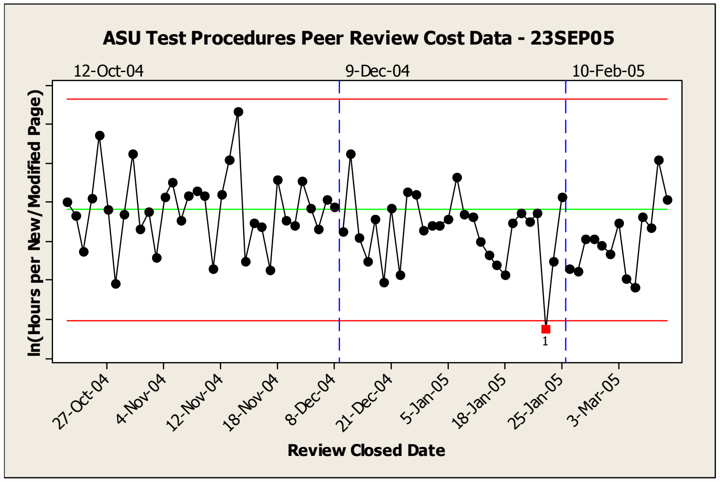
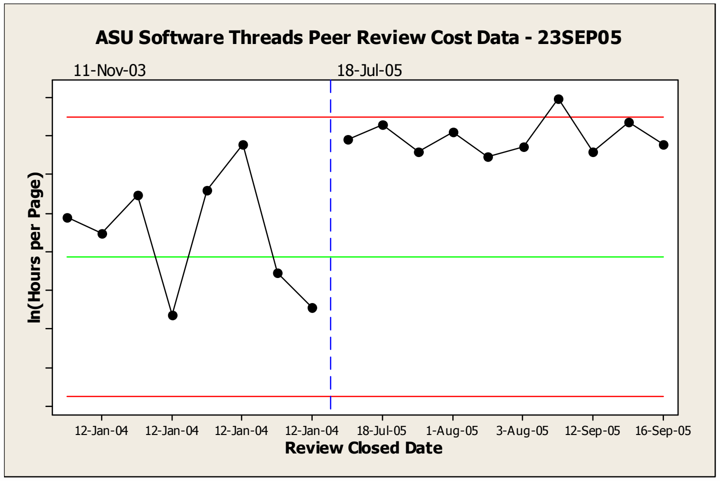
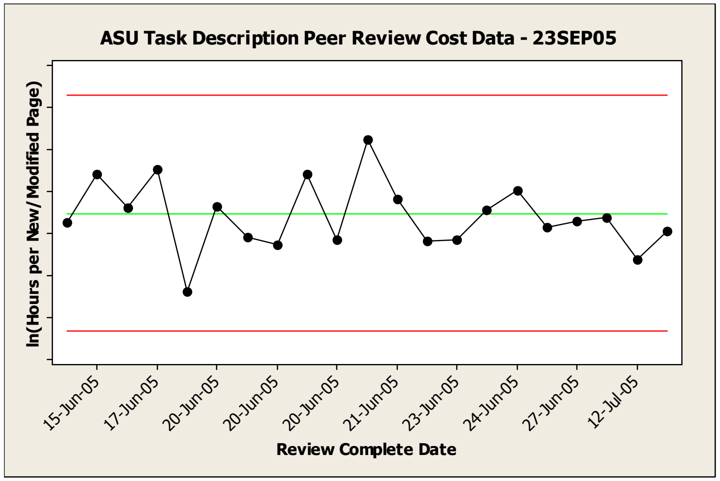
Expanding the Capability

- Test, SW Design









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Summary

With the Log-cost Model

- ***Peer Review Subprocesses Are In-control and Capable* of Meeting Baseline Budget Allocations**
- ***Due Diligence Is Rewarded***
- ***Superficial Reviews Are Detected***
- ***False Alarm Rate Reduced***
  - *Greater Than 40× Improvement*

Enhanced Sub-Process Control for CMMI Levels 4 and 5

QUESTIONS

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