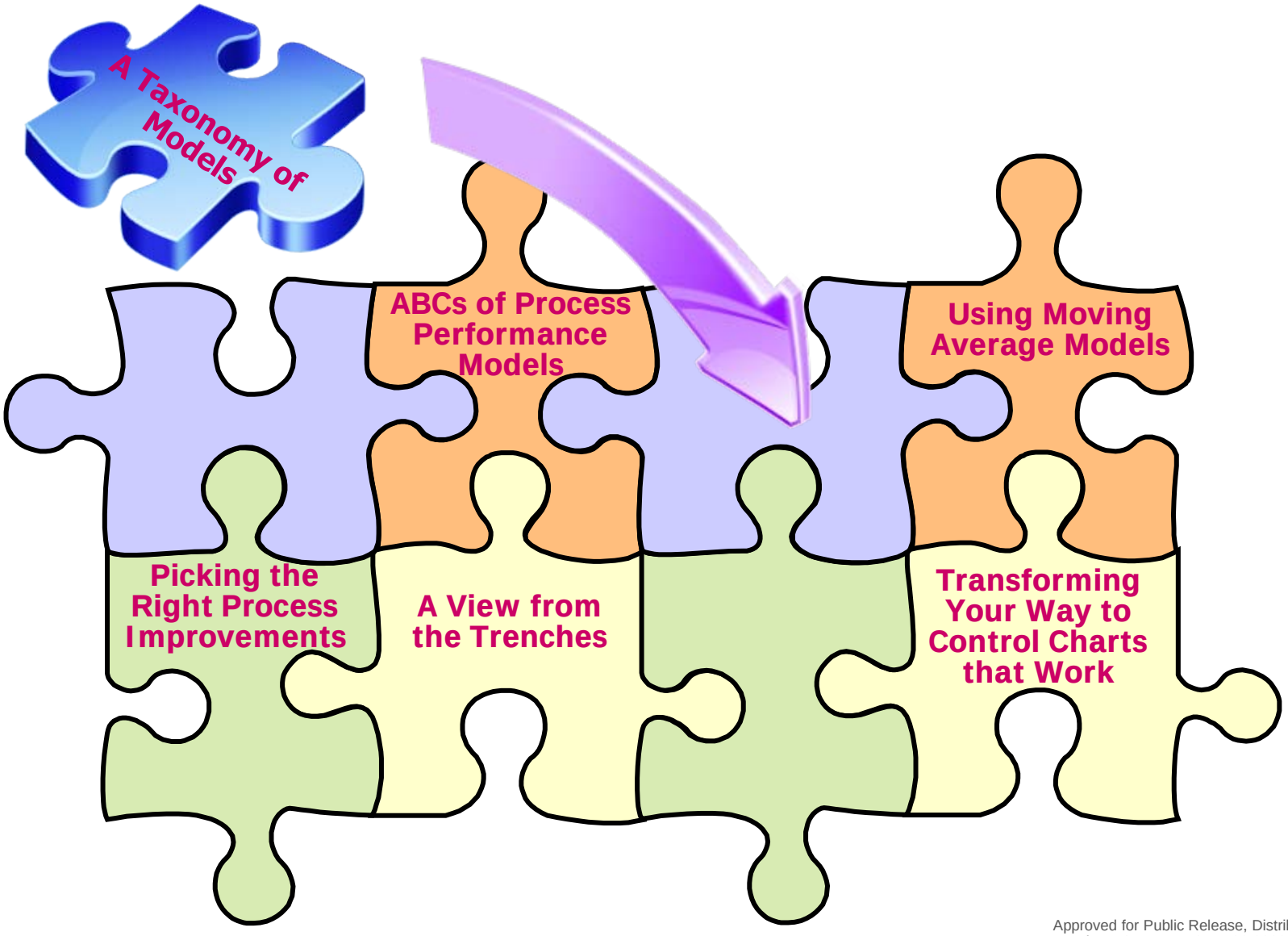
NORTHROP GRUMMAN

A Taxonomy of CMMI® High Maturity Performance Models

November 18, 2009

Richard L. W. Welch, PhD
Associate Technical Fellow
Northrop Grumman Corporation

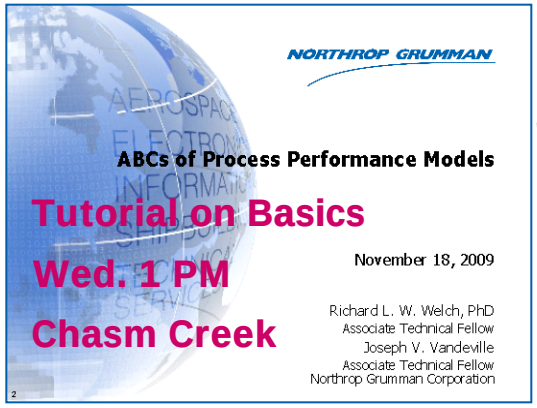
The High Maturity Puzzle

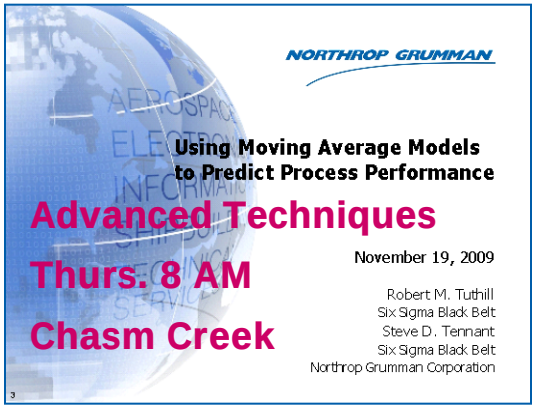


The First Piece of the Puzzle

- The High Maturity Puzzle
- Families of Models
  - Process decomposition
  - Quality
  - Statistical process control (control charts)
  - Log-cost
  - Parametric estimation
  - Grass-roots estimation
  - Traditional project management
  - Decision
  - Ad hoc
- Fitting the Puzzle Together

The Other Puzzle Pieces





What is a Process Performance Model?

NORTHROP GRUMMAN

- To a CMMI wonk, a model is

  A description of the relationships among attributes of a process and its work products that is developed from historical process-performance data and calibrated using collected process and product measures from the project and that is used to predict results to be achieved by following a process

  (From the *CCMI for Development*, Version 1.2)

- To a mathematician,

  A real-valued function (or time series) that predicts quality & process performance results

Something that predicts the future

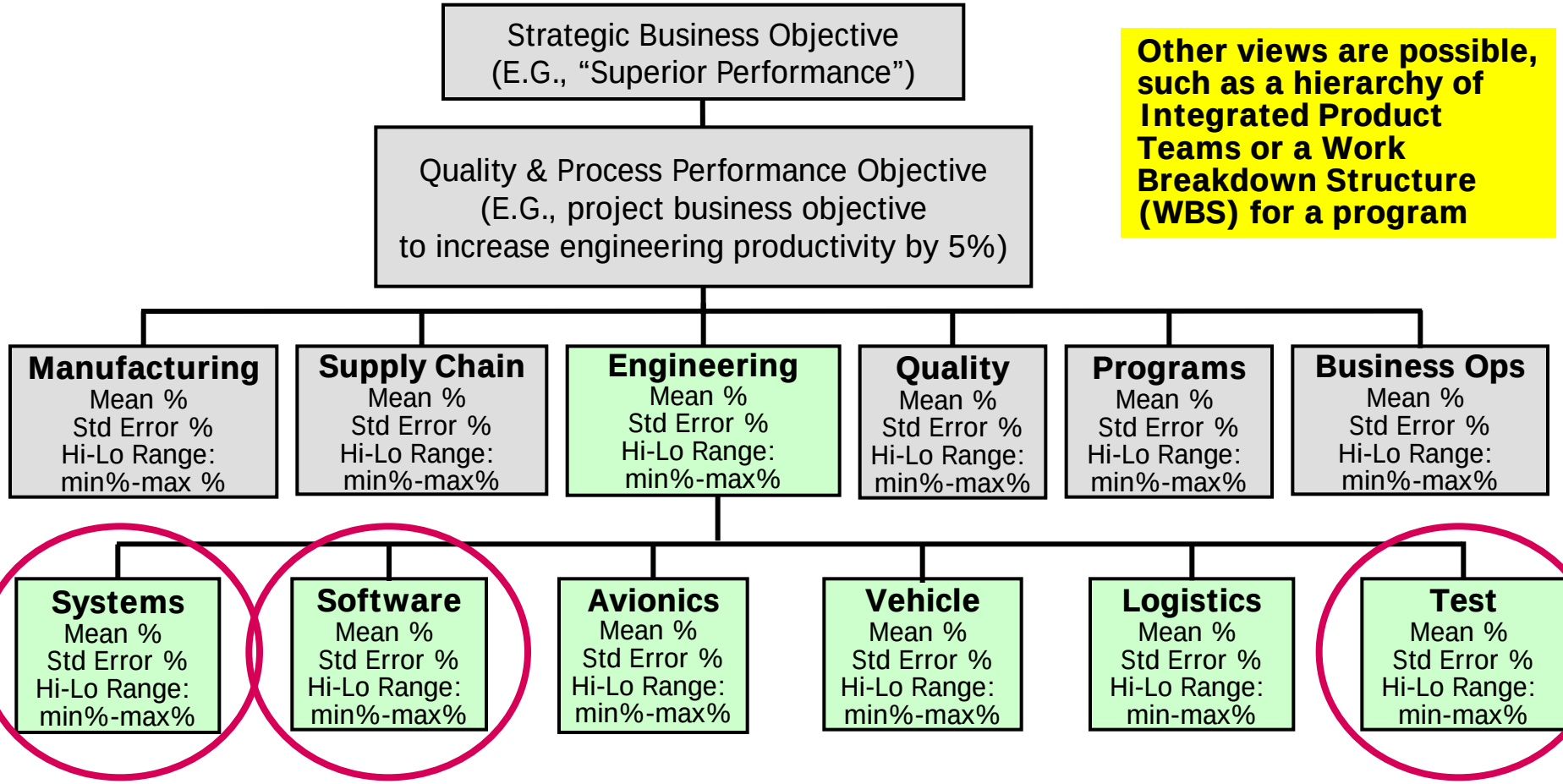
Process Decomposition Models

NORTHROP GRUMMAN

- Used to relate the relative contribution of a sub-process at a lower level of a decomposed process to a higher level of the process, and vice versa
- These models are linear transformations, so sub-process baselines (characterized by the mean and standard deviation, or mean and range) are propagated linearly through the model

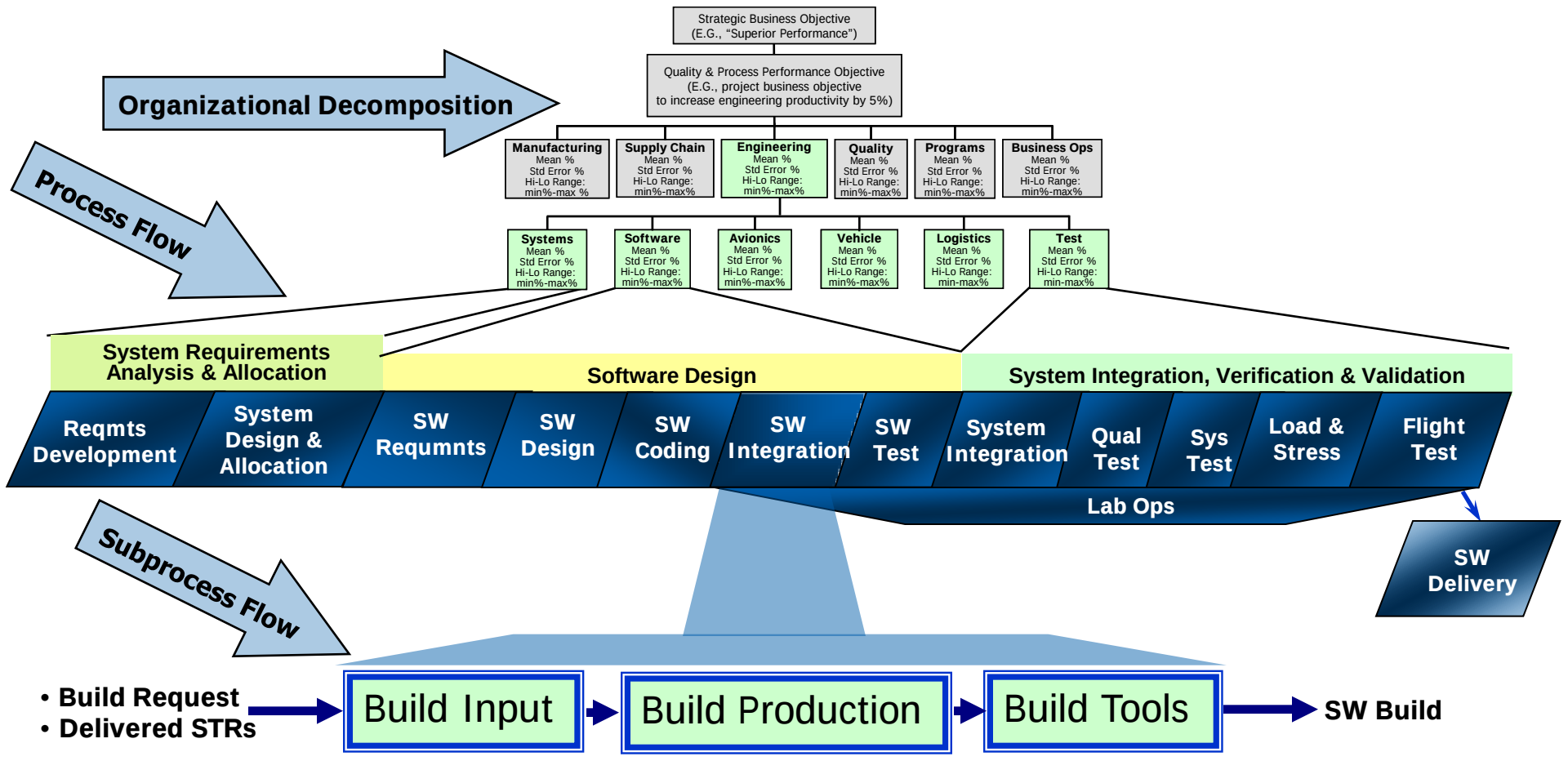
Model Type	Stochastic
Predicted Outcomes	Labor effort or other work share metric at another level of the process decomposition
Input Attributes	Labor effort or other work share metric
Related Quality & Process Performance Objectives	All (cost, schedule, quality, process performance, executability, technical performance, risk, etc.)

Organizational Decomposition



Contribution of labor effort for each group derived from project actuals. Can be calibrated to a specific project, program or process average

Process Decomposition

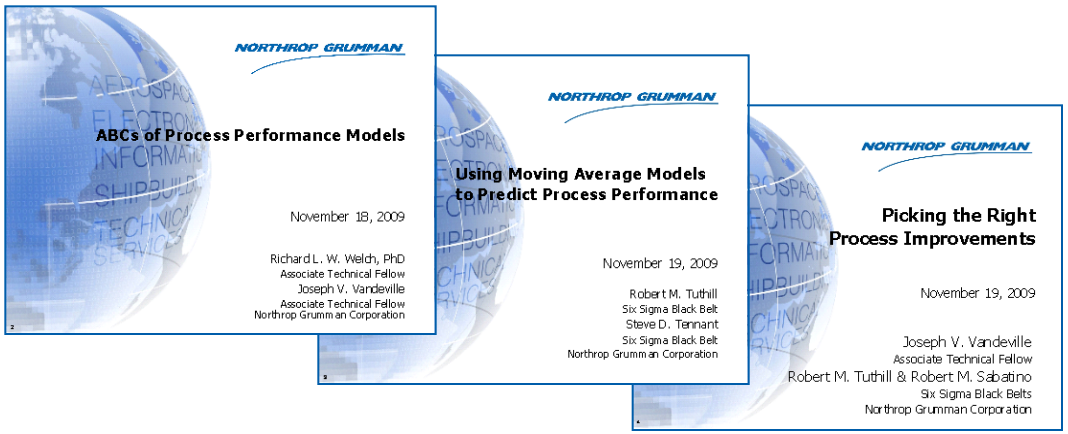


Contribution of labor effort for each model element derived from project actuals; project data characterized by mean, standard error & hi-lo. Can be calibrated to a specific project, program or process average range

Mean %
Std Error %
Hi-Lo Range:
min%-max%

Decomposing a QPPO Down to Sub-process Performance

- Identify the quality & process performance objective (QPPO)
- Decompose the top-level organizational performance model into critical processes & subprocesses
  - This model provides an understanding of the relationship between processes & subprocesses on the one hand and QPPOs on the other
  - Linear transformation propagates the statistics to each level
- Necessary to demonstrate how sub-process baselines & models predict achievement of QPPOs



Quality Models

NORTHROP GRUMMAN

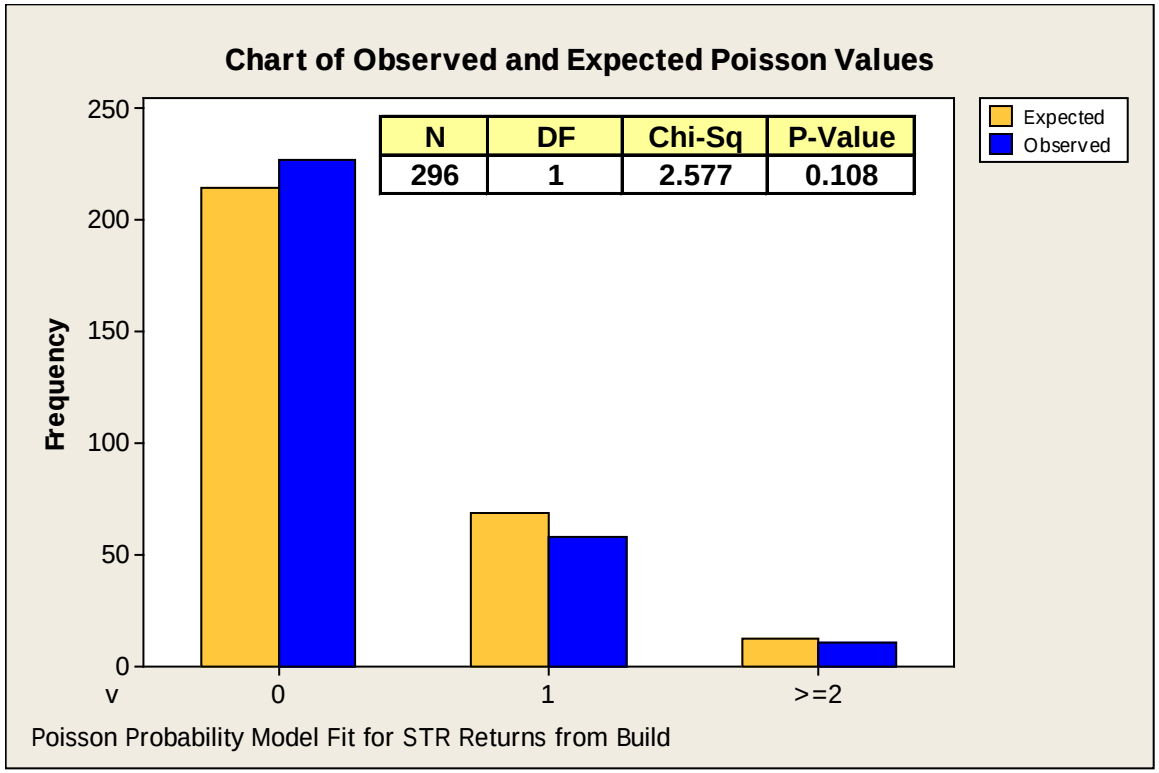
- Used to predict output quality levels and downstream impact of error escapes

Model Type	Stochastic
Predicted Outcomes	Quality levels & associated confidence or risk
Input Attributes	Work product type (e.g., drawing type, code, requirements, design artifact), development phase
Related Quality & Process Performance Objectives	Quality & rework levels

Build Returns Probability Model

Value	Observed Frequency	Poisson Probability	Expected Frequency	Contribution to Chi-Sq
0	227	0.73	214.73	0.70
1	58	0.23	68.91	1.73
>=2	11	0.04	12.34	0.15

- Poisson probability model is used to develop a quality performance model
- The Poisson probability distribution exhibits the ability to model the number of Build Returns in future builds
- First pass yield of the build process is 73%



Statistical Process Control (e.g., Control Charts)

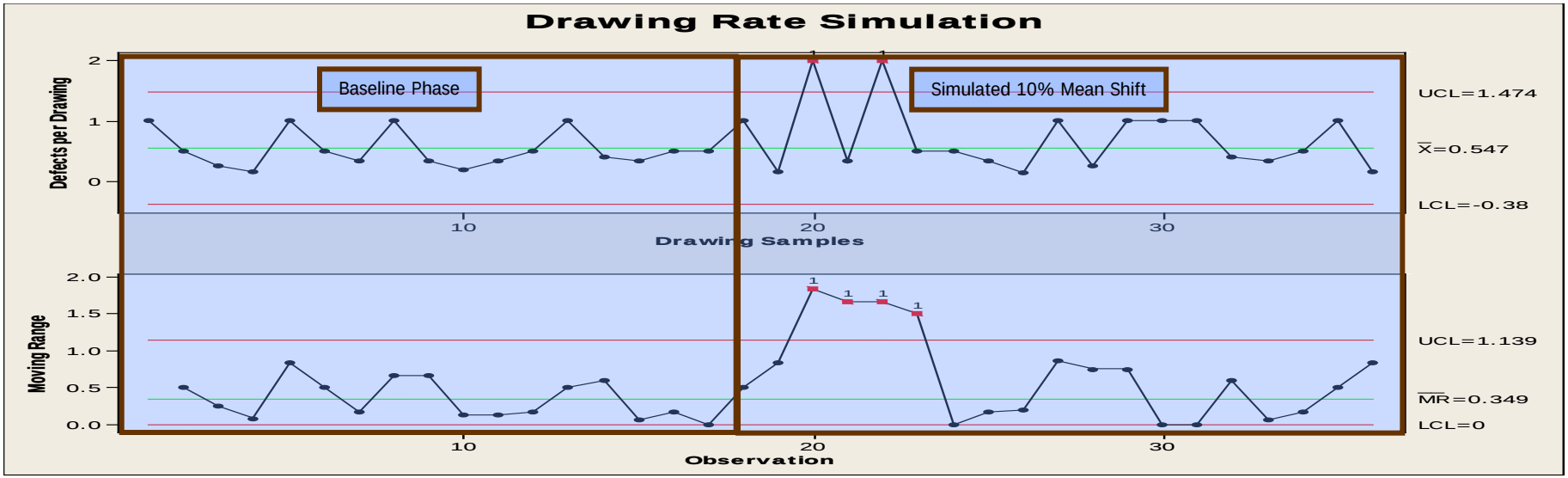
NORTHROP GRUMMAN

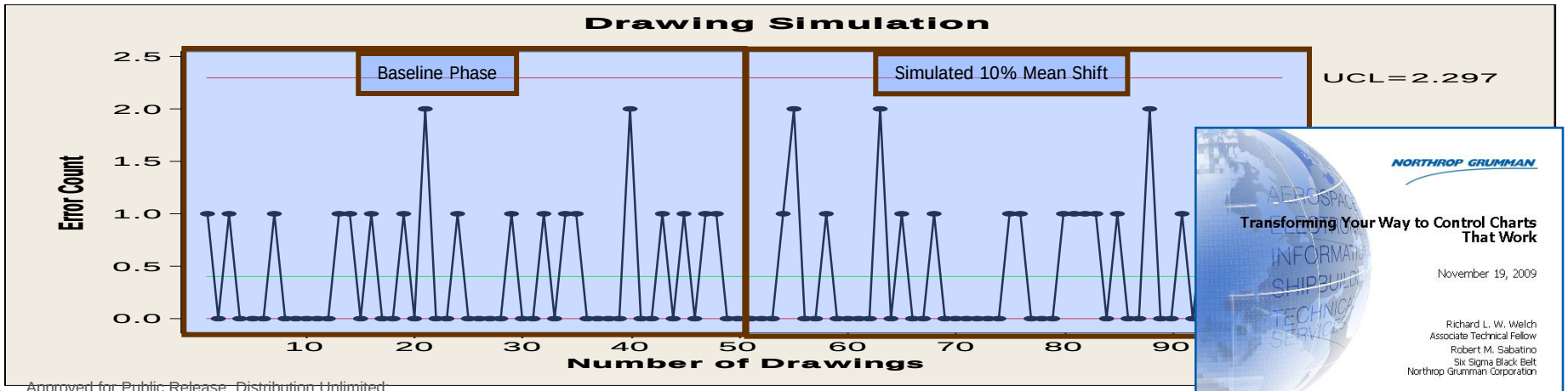
- Used to manage and control subprocess behavior its own the data
- High maturity organizations can control lots of subprocess. Currently, we control about 50 subprocesses in all disciplines and all phases of product development

Model Type	Stochastic
Predicted Outcomes	Predicted output metrics are the mean and standard error of the controlled sub-process performance attribute
Input Attributes	Control variables are product or process attributes of cost, schedule or quality for the controlled sub-process
Related Quality & Process Performance Objectives	Project & process management

Sensitivity Comparison

- This simulation models a 10% process shift
- What chart would you use?





Log-Cost

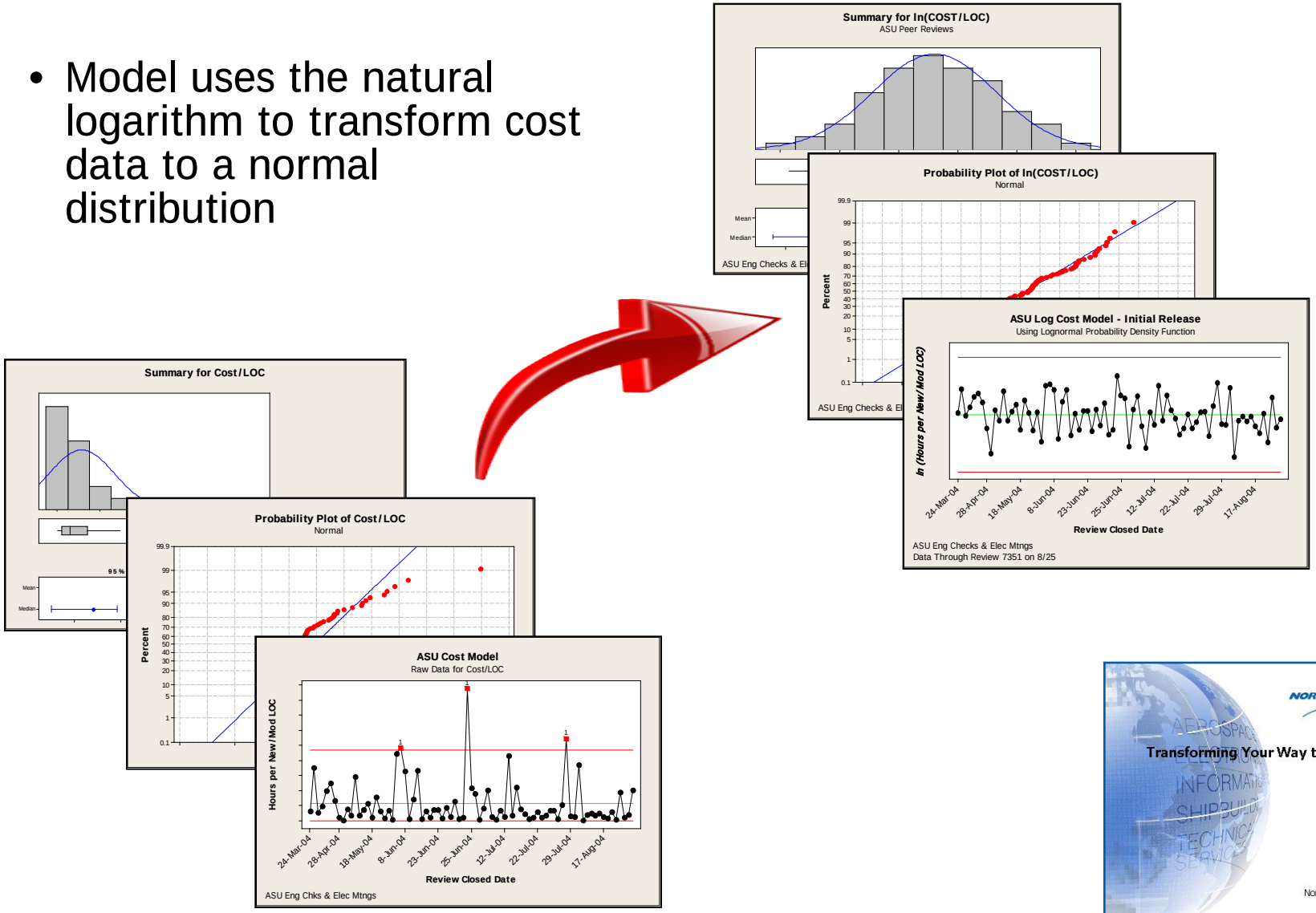
NORTHROP GRUMMAN

- Enables more effective statistical process control of peer review and other product development costs that follow a lognormal density model
- Used by all Engineering disciplines

Model Type	Stochastic
Predicted Outcomes	Log-Cost; predicted output metrics are the geometric mean and standard error of the peer review cost
Input Attributes	Engineering labor effort to perform a peer review, size of artifact reviewed (e.g., code size)
Related Quality & Process Performance Objectives	Project & process management

ln Transform

- Model uses the natural logarithm to transform cost data to a normal distribution



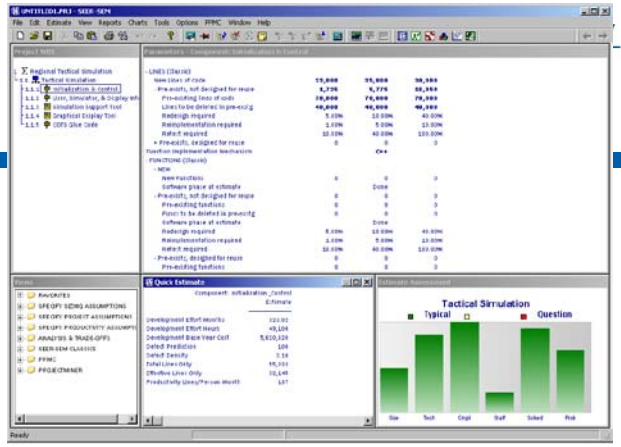
Parametric Estimation

NORTHROP GRUMMAN

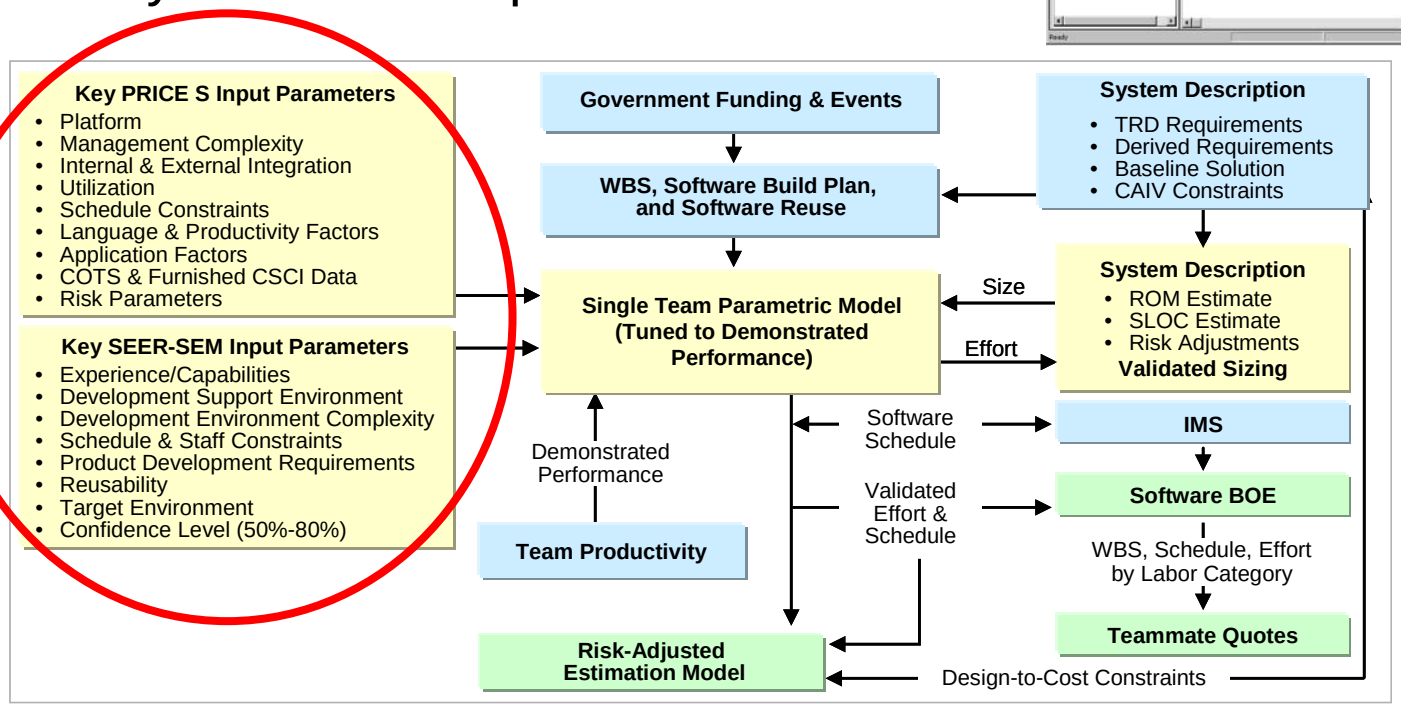
- Software development estimates generated with parametric tools, like SEER-SEM™ or Price S
  - Generated initially with optimal cost, then tailored to minimum time to ensure all Integrated Master Schedule SW milestones can be met with margin
  - Project's composed SW process must comply with model constraints
- Model productivity calibrated to past performance on comparable jobs
- Model parameters are modeled stochastically with triangular distributions
  - Executability risk validated with Monte Carlo simulation against management targets

Model Type	Stochastic
Predicted Outcomes	Cost, schedule, staffing
Input Attributes	Confidence level; code size; personnel capabilities & experience; development support environment; product development requirements; product reusability requirements; development environment complexity; target environment; schedule & staffing constraints
Related Quality & Process Performance Objectives	Cost control

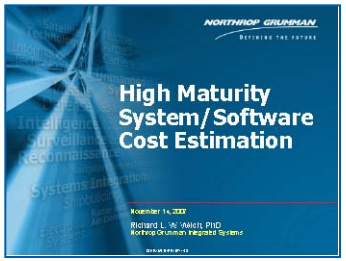
Parametric Tools Work



- Very accurate – when properly calibrated & used
- Know your Customer preference



Recognize that your bid defines your process



Grass-Roots Estimation

- Traditional cost models of the form *Quantity* X *Rate* = *Cost*, used for bottoms-up cost estimation & sanity checks of parametric models
- Cost Estimating Relationships (CERs) based on statistical regression analysis of actuals from product development projects

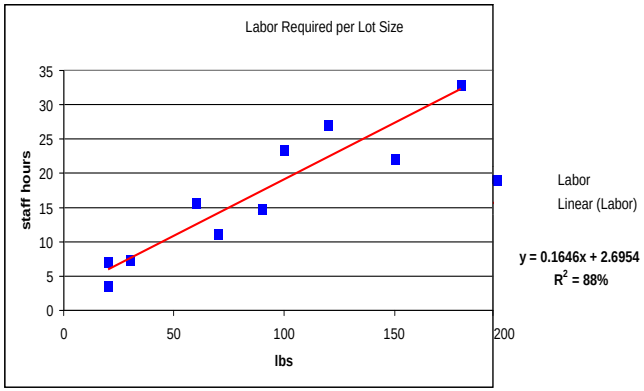
Model Type	Stochastic & Deterministic
Predicted Outcomes	Cost
Input Attributes	Basis of estimate rates, categorized by product or project characteristics (e.g., drawing type, software project type); expected project size or quantity (e.g., code size, drawing count). For statistically derived estimates, input also includes the desired confidence level (i.e., probability) for the estimate
Related Quality & Process Performance Objectives	Cost control

Establishing a Cost Estimating Relationship

- Uses statistical regression analysis to relate the amount of a material produced to the staff hours needed for production
  - The material represents a generic commodity
  - Microsoft Excel > Chart > Add Trendline . . .
- CER is the regression equation

  Labor Hours = 0.165*(Pounds of material per lot) + 2.7

Lot	x (lbs)	y (hrs)
1	20	3.5
2	30	7.4
3	20	7.1
4	60	15.6
5	70	11.1
6	90	14.9
7	100	23.5
8	120	27.1
9	150	22.1
10	180	32.9



Example taken from Rodney Stewart, *Cost Estimating*, 2nd ed., 1991

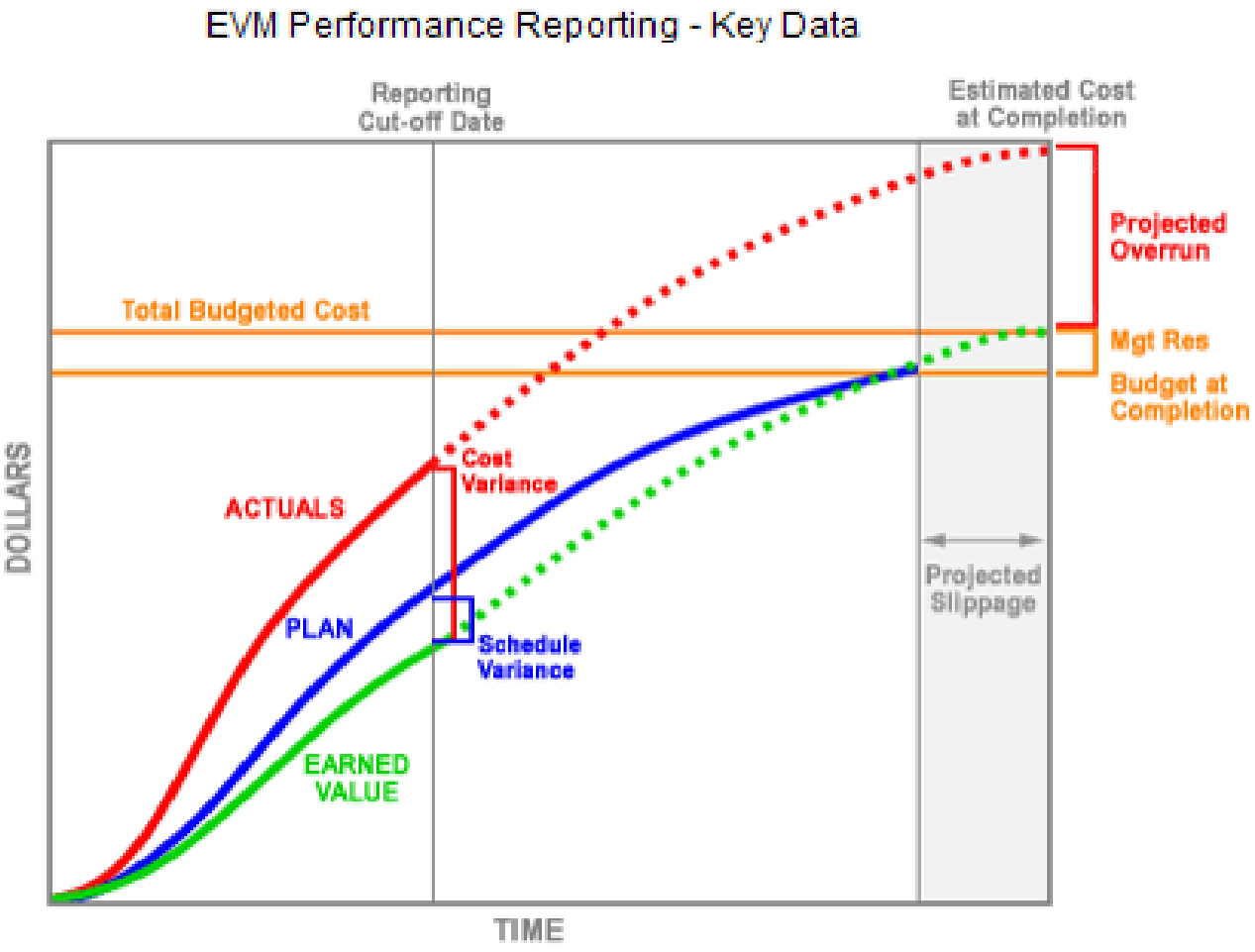
Traditional Project Management

NORTHROP GRUMMAN

- Estimate at completion forecasts of cost & schedule, based on earned value metrics; staffing projections

Model Type	Deterministic
Predicted Outcomes	Cost, schedule and staffing performance
Input Attributes	Earned value, staffing levels
Related Quality & Process Performance Objectives	Project & process management (i.e., cost & schedule)

Earned Value Reporting



Example taken from NASA's Earned Value Management (EVM) tutorial

Decision

- Used by senior Engineering management to prioritize and select process improvement candidates for organizational innovation & deployment activities; also used by project technical and program management to prioritize and select trade study alternatives

Model Type	Analytic Hierarchy
Predicted Outcomes	Weighted decision score
Input Attributes	Decision criteria and weights
Related Quality & Process Performance Objectives	All

Process Improvement Trade Studies

NORTHROP GRUMMAN

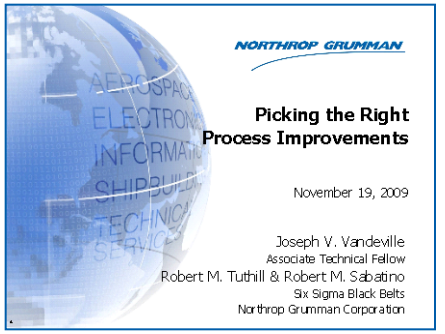
. . . How do I determine this

Prioritized Improvement Projects

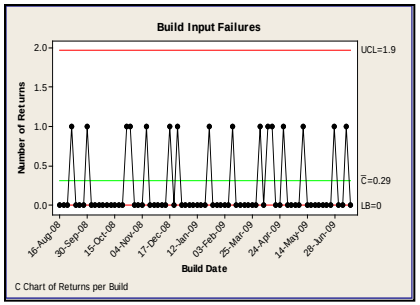
Given this . . .

Organizational Goals
Organizational Objectives
Project Needs
Lessons Learned
Improvement Opportunities
Critical Processes
. . .

Trade Study !

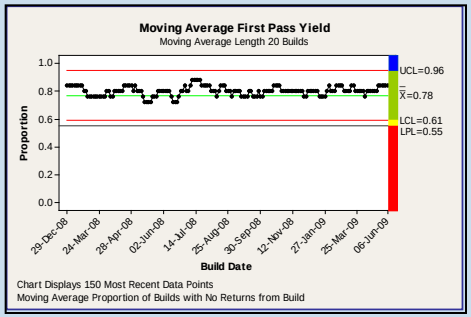


Fitting the Puzzle Together



Sub-process control (C-Chart) provides identification of instantaneous changes in process performance that predict trends in moving average model

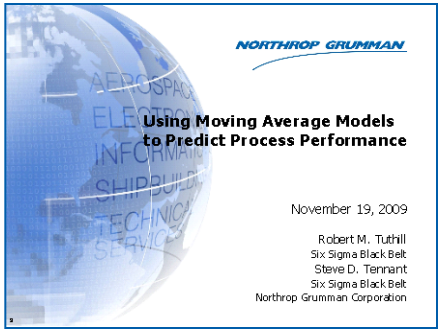
Trends in moving average model predict impacts to achievement of the QPPO (SPI)



Notional Data

SPI	Project Color Rating
1.00	
0.99	
0.98	
0.97	
0.96	
0.95	
0.94	
0.93	
0.92	
0.91	
0.90	

Demonstrating how a sequence of models predicts achievement of the project's quality & process performance objective



Richard L. W. Welch, PhD
Northrop Grumman Corporation
(321) 951-5072
Rick.Welch@ngc.com