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DEFINING THE FUTURE

A Practical Guide to Implementing Levels 4 and 5

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Agenda

- **An Overview of Levels 4 and 5**
  - New Behaviors
  - Benefits – Project, Organizational, Customer
  - Making the Business Case
- **Understanding the CMMI Process Areas**
  - Organizational Process Performance
  - Quantitative Project Management
  - Causal Analysis & Resolution
  - Organizational Innovation & Deployment
- **Strategies for Adoption**
  - Lessons Learned
  - References

Management Styles in the CMMI

Project

Quantitative management

Proactive management

Reactive mgmt. (plan, track, and correct)

Organizational

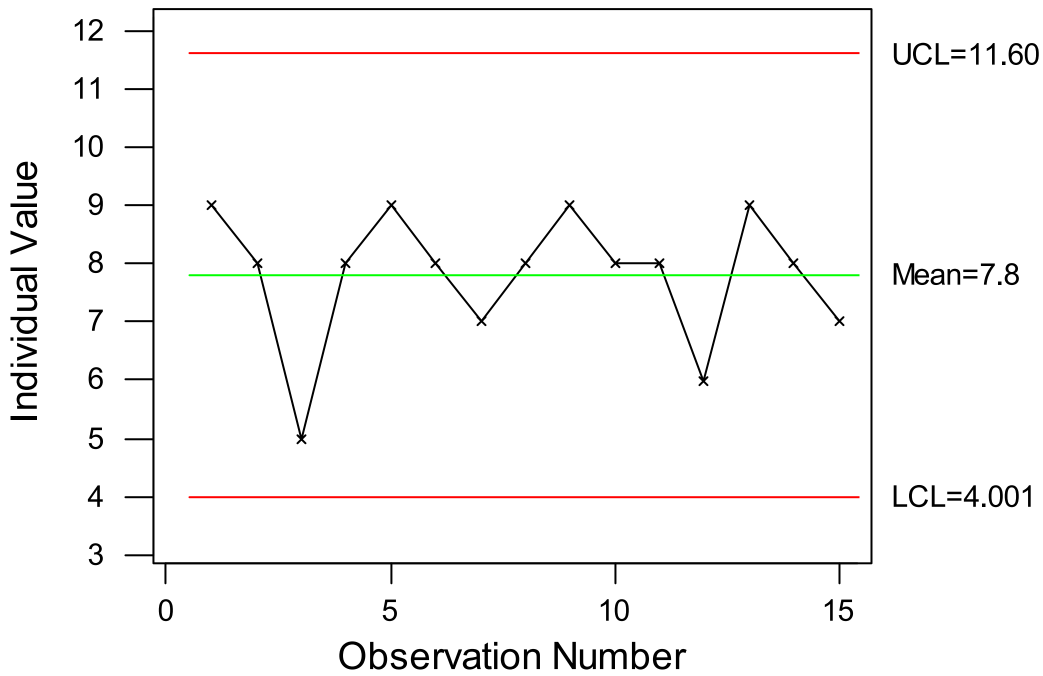
Quantitative improvement

Qualitative improvement

Level	Process Areas
5 Optimizing	Causal Analysis and Resolution Organizational Innovation and Deployment
4 Quantitatively Managed	Quantitative Project Management Organizational Process Performance
3 Defined	Requirements Development Technical Solution Product Integration Verification Validation Organizational Process Focus Organizational Process Definition Organizational Training Risk Management Integrated Project Management (for IPPD*) Integrated Teaming* Integrated Supplier Management** Decision Analysis and Resolution Organizational Environment for Integration*
2 Managed	Requirements Management Project Planning Project Monitoring and Control Supplier Agreement Management Measurement and Analysis Process and Product Quality Assurance Configuration Management
1 Performed	

Exercise – What is Quantitative Management?

- **Suppose your project conducted several peer reviews of similar code, and analyzed the results**
  - Mean = 7.8 defects/KSLOC
  - +3σ = 11.60 defects/KSLOC
  - -3σ = 4.001 defects/KSLOC



- **What would you expect the next peer review to produce in terms of defects/ KSLOC?**
- **What would you think if a review resulted in 10 defects/KSLOC?**
- **3 defects/KSLOC?**

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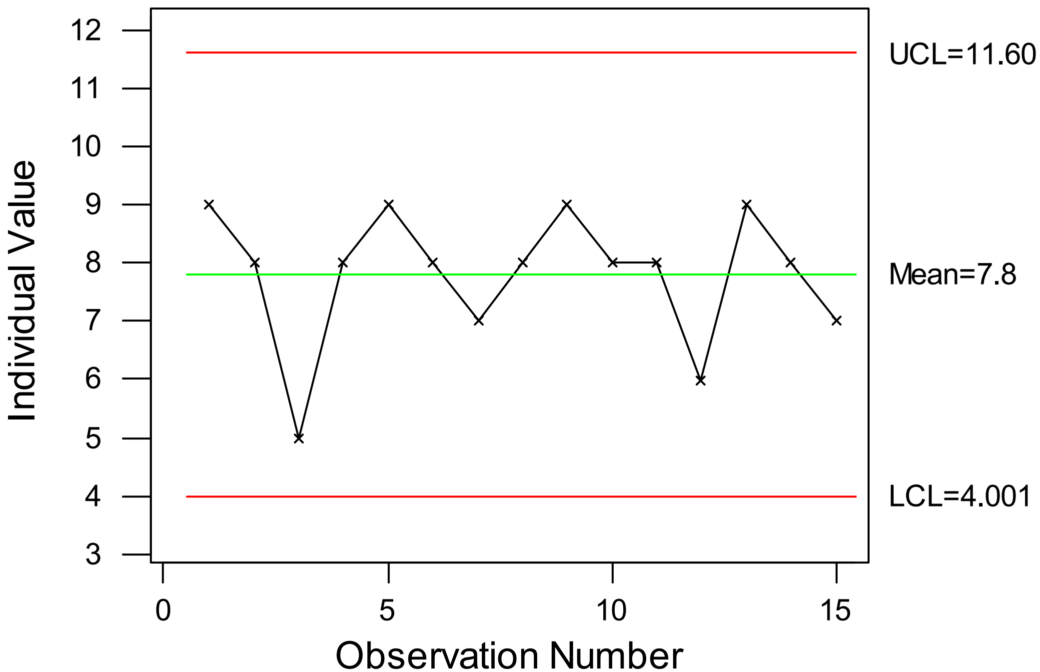
Exercise –
What is Required for Quantitative Management?

- **What is needed to develop the statistical characterization of a process?**



- **The process has to be stable (predictable)**
  - Process must be consistently performed
  - Complex processes may need to be stratified (separated into simpler processes)
- **There has to be enough data points to statistically characterize the process**
  - Processes must occur frequently within a similar context (project or organization)

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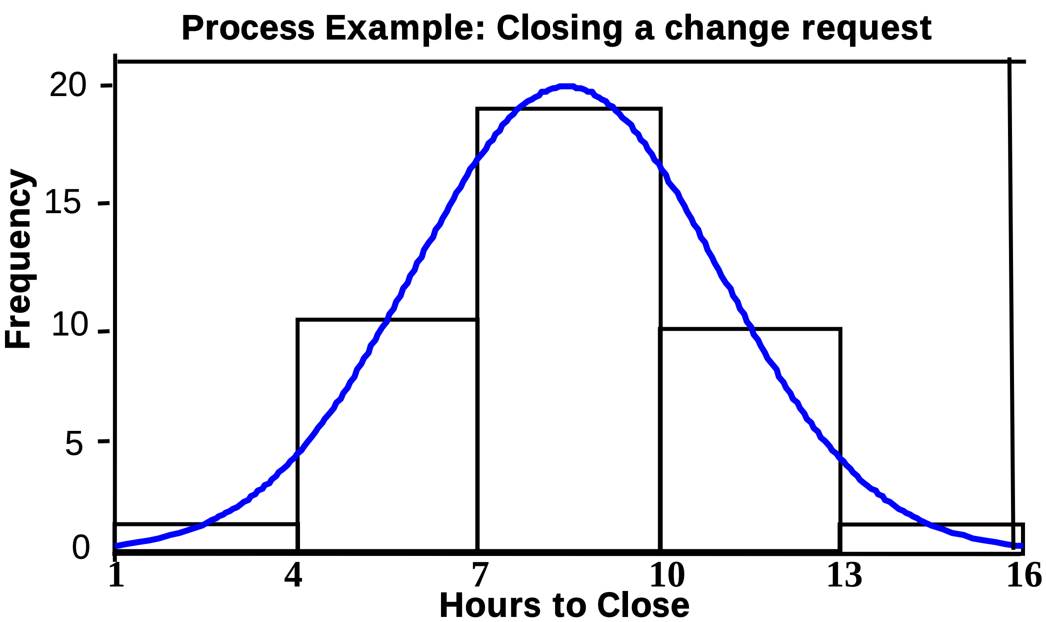
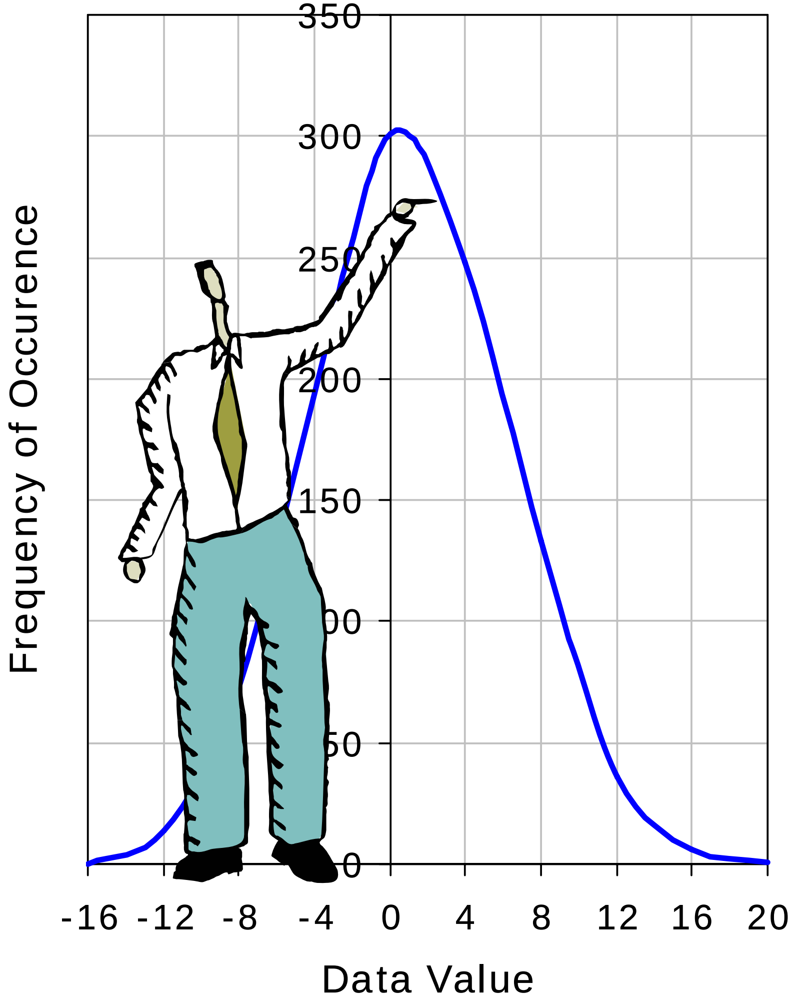
What Is a Data Distribution?



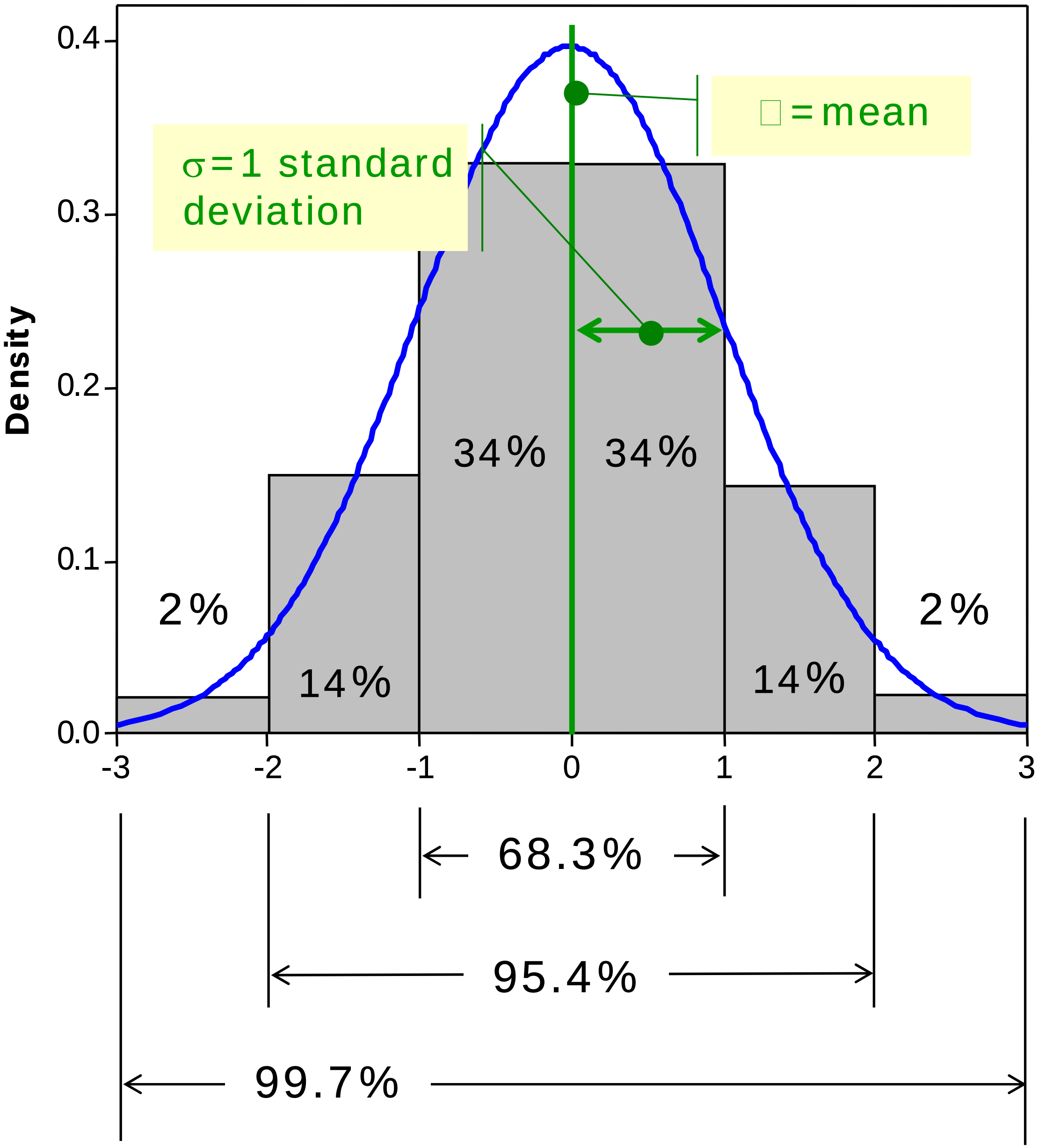
- The data distribution gives a frequency of occurrence of each value in a data set
- Once we characterize the data distribution, we can predict future values or assign a probability to any specific value
- Data distributions may represent population or process data
- When applied to process data - assumes statistical stability

The Normal Distribution



- **Commonly called a bell curve; formally called a Gaussian distribution**
- **Applies to continuous data (e.g. time, weight, distance)**
- **Characteristic shape:**
  - Mean, mode, and median are all the same value
  - Standard deviation is independent of the mean
- **Normal distributions are not a law, but they are often observed in natural data**

Characteristics of a Normal Curve



Once we understand what kind of distribution our data comes from, we can predict future values or assign a probability to any specific point

- Probability x will occur
- Probability a value < x
- Probability a value > x
- Probability a value will occur between x and y

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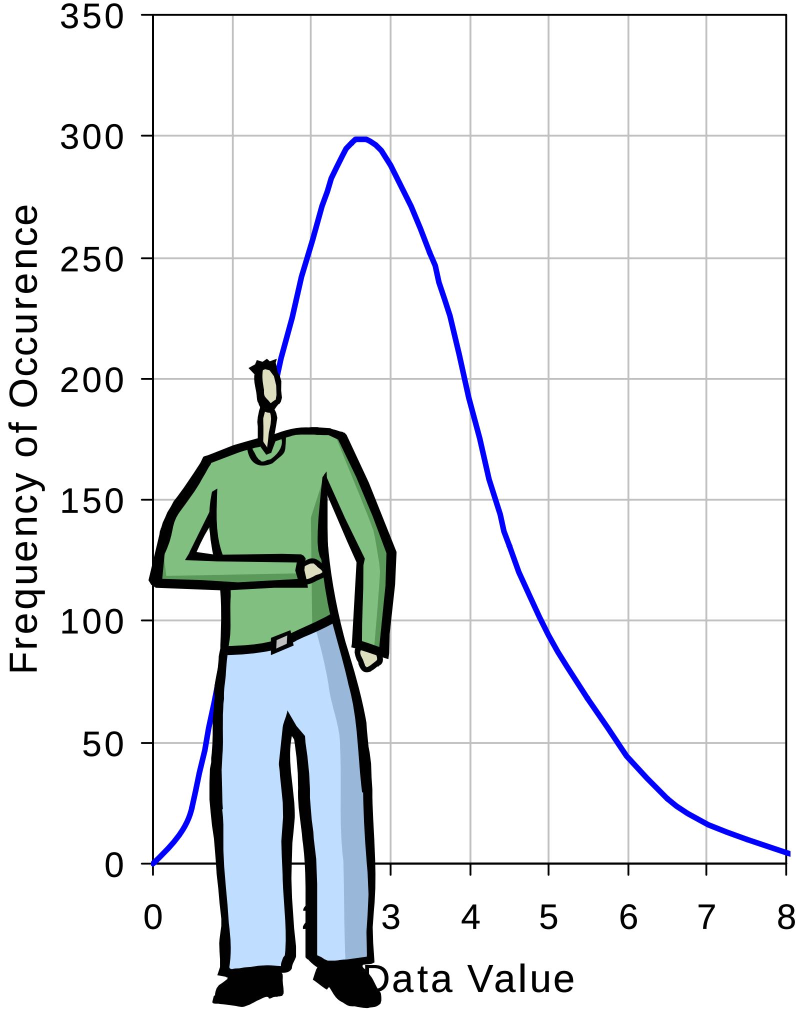
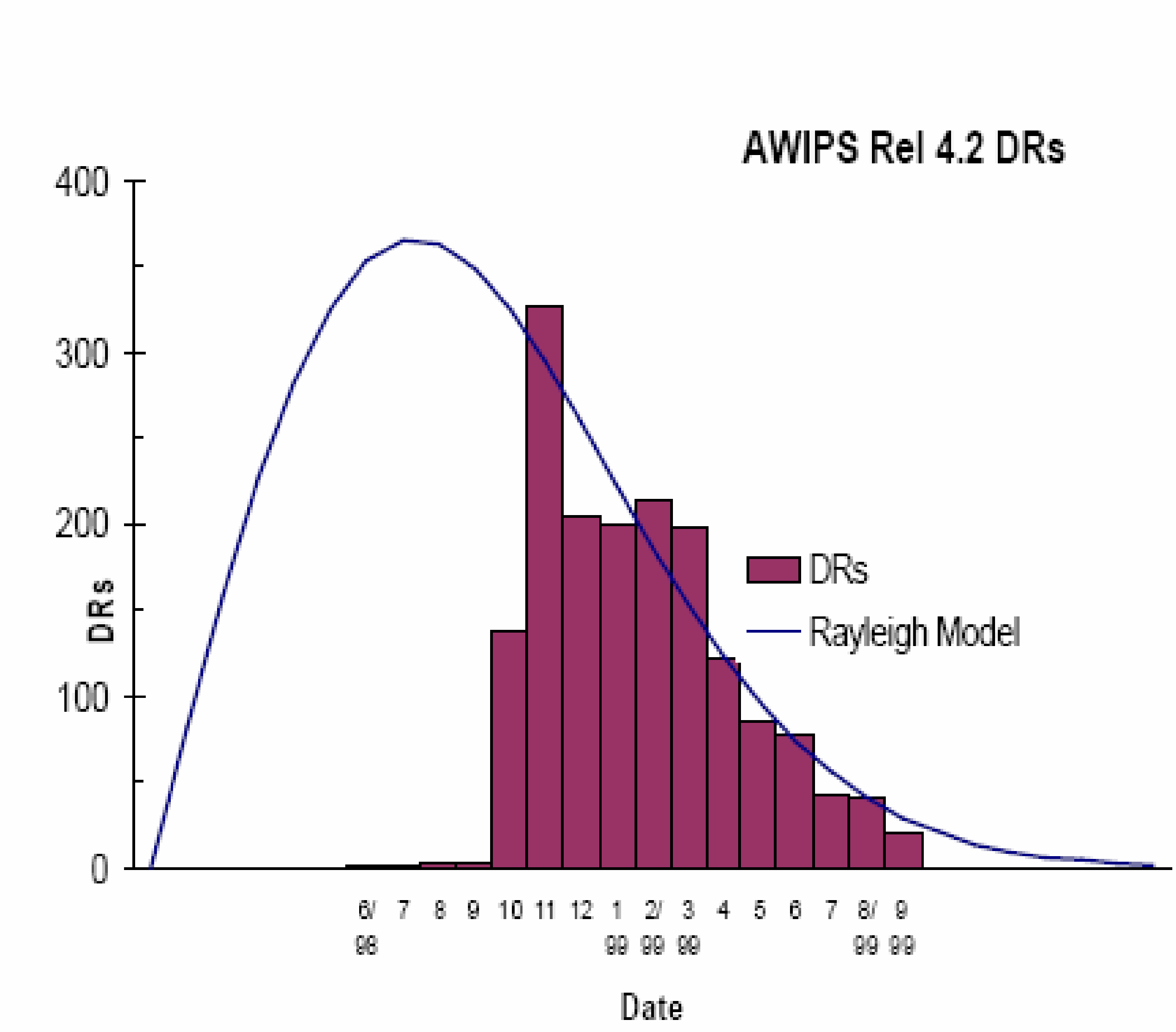
The Rayleigh Distribution…



- **A skewed distribution**
- **Used to model effort or defect density in software development where the abscissa represents development phase if they are roughly the same duration**

Example - Defect Detection

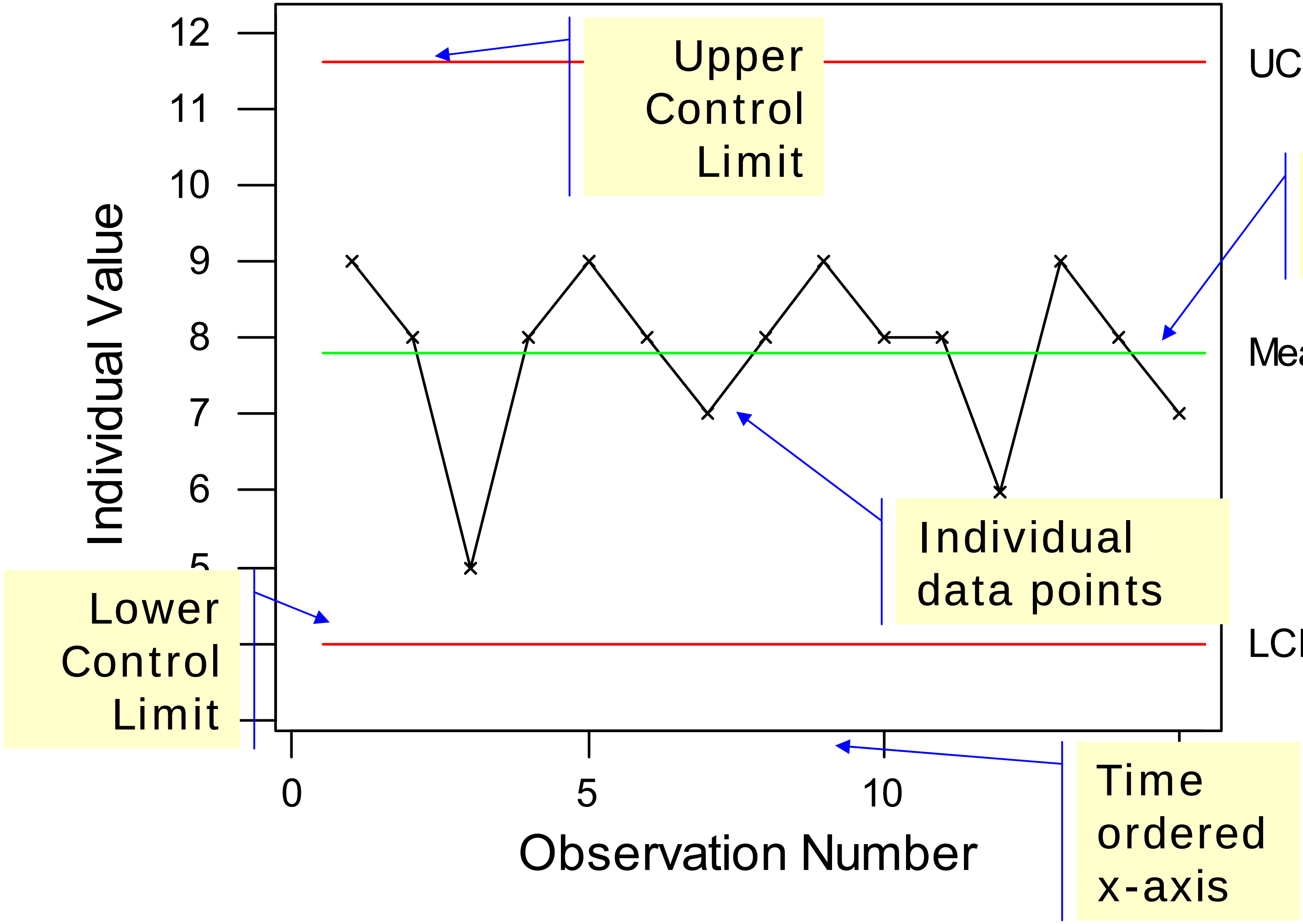


"Business Value and Customer Benefits Derived from High Maturity", Al Pflugrad, CMMI Technology Conference and User Group, 2002

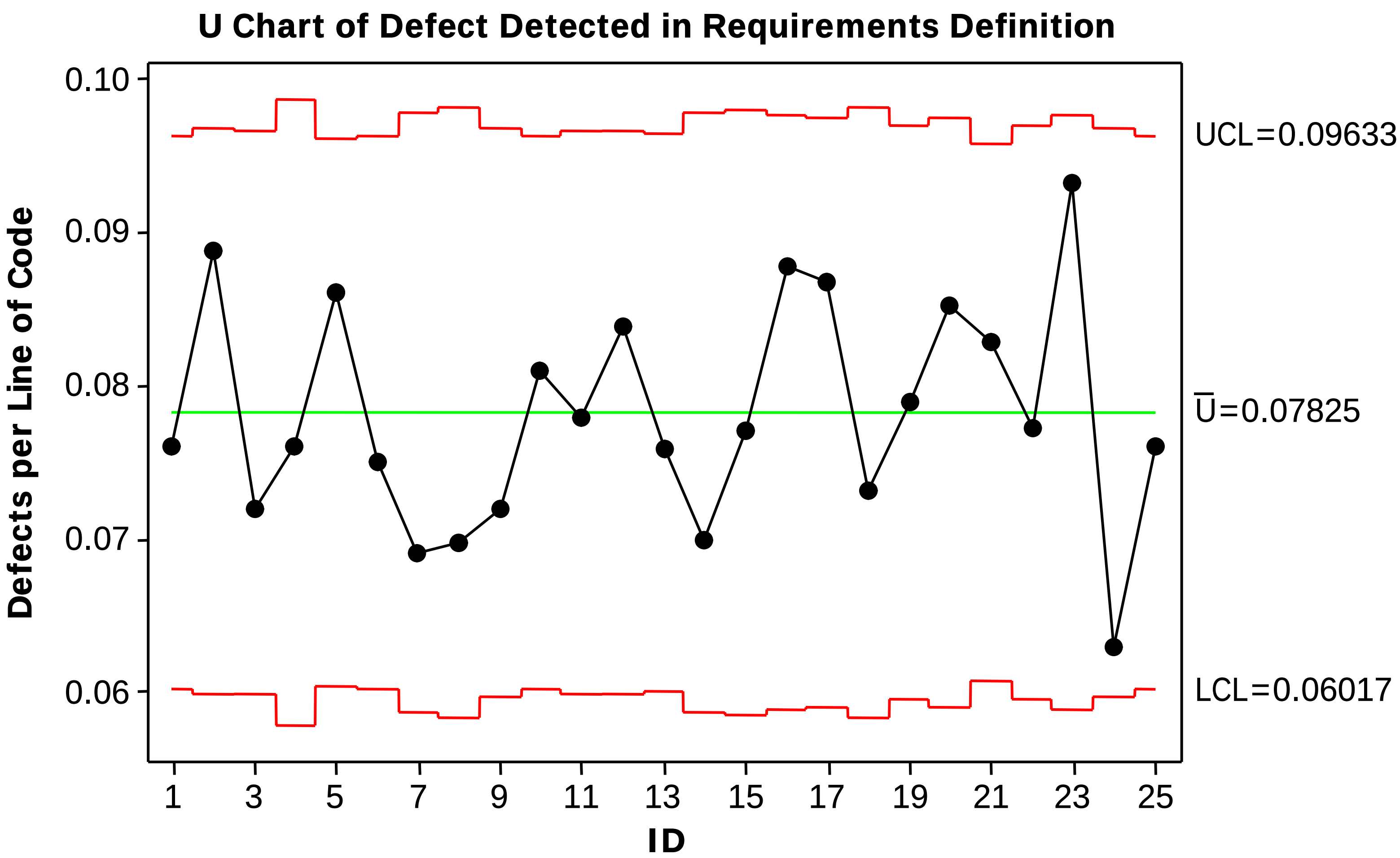
What Is a Control Chart?

- A time-ordered plot of process data points with a centerline based on the average and control limits that bound the expected range of variation
- Control charts are one of the most useful quantitative tools for understanding variation

What Are the Key Features of a Control Chart?



There are Many Types of Control Charts



Tests performed with unequal sample sizes

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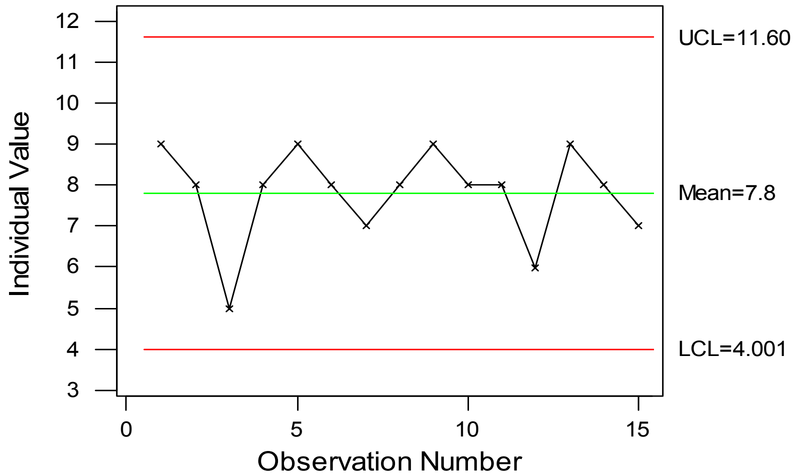
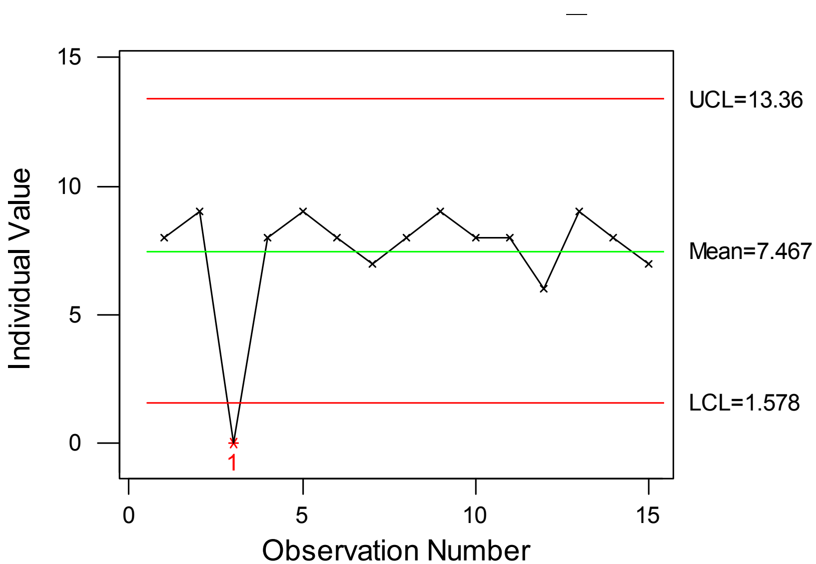
What is *Special Cause* and *Common Cause* Variation?



- **Common Cause Variation**
  - *Routine* variation that comes from within the process
  - Caused by the natural variation in the process
  - Predictable (stable) within a range



- **Special Cause Variation**
  - *Assignable* variation that comes from outside the process
  - Caused by a unexpected variation in the process
  - Unpredictable

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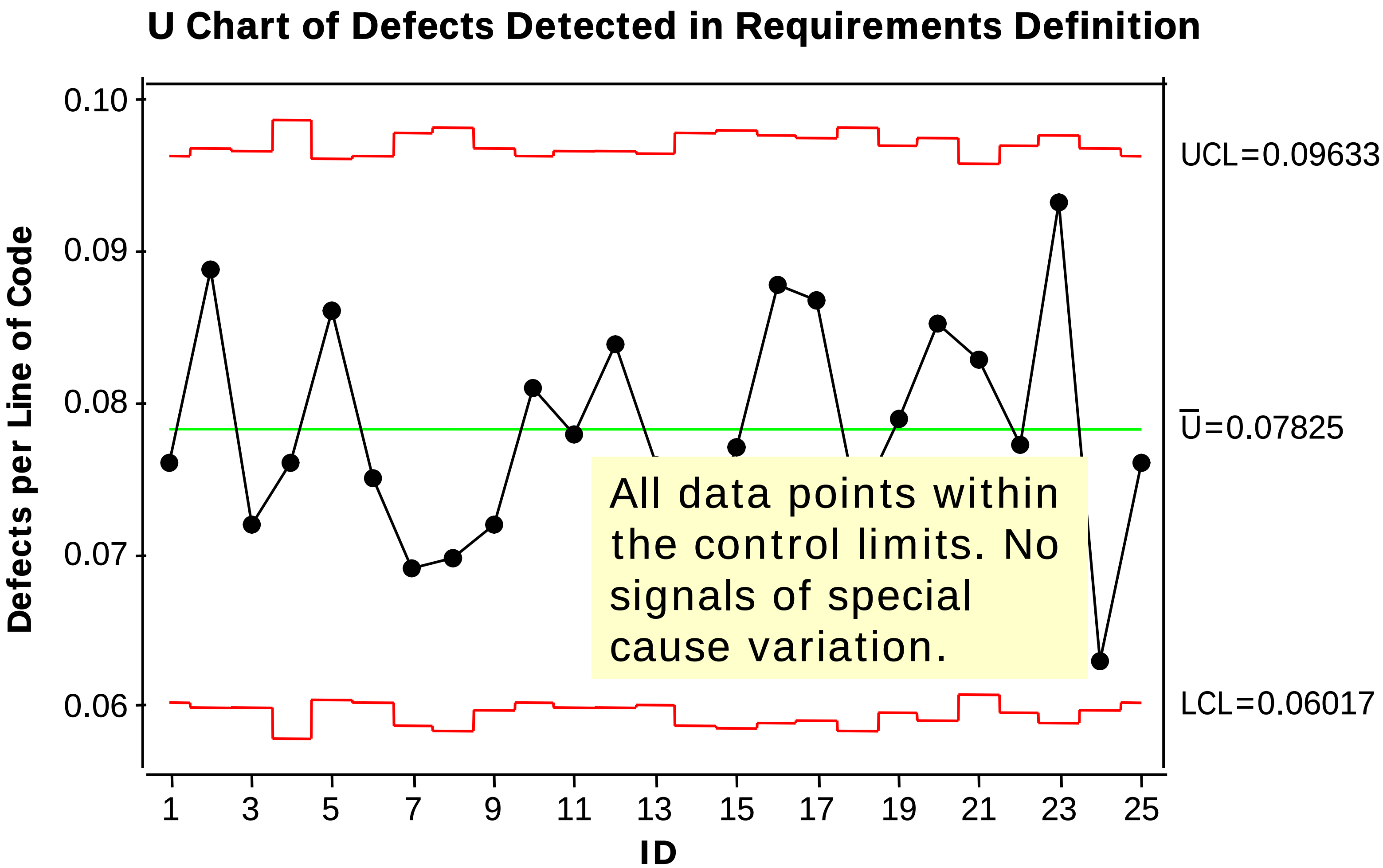
What Is a *Stable* (Predictable) Process?



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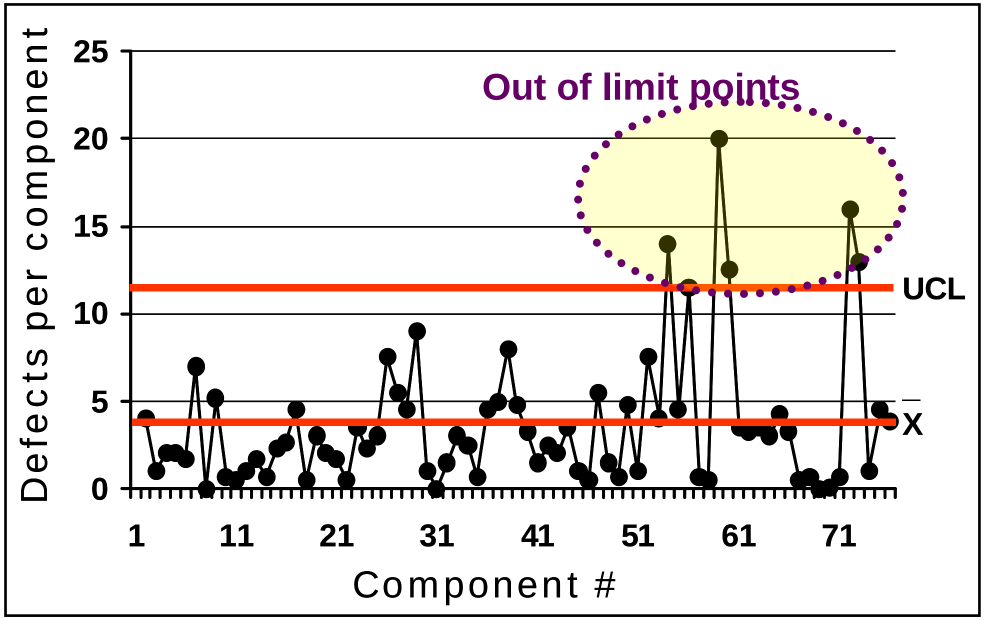
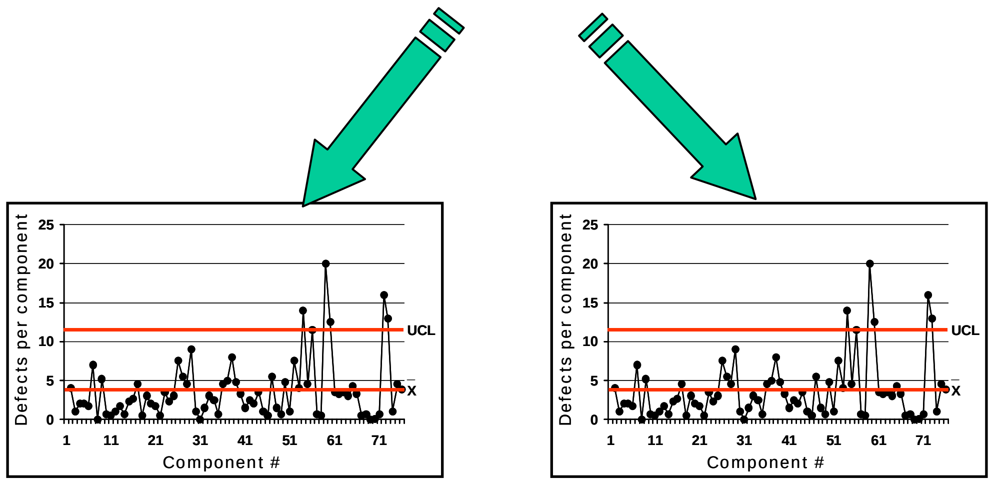
What if the Process Isn't Stable?

- **You may be able to explain out of limit points by observing that they are due to an variation in the process**
  - E.g., peer review held on Friday afternoon
  - You can eliminate the points from the data, if they are not part of the process you are trying to predict



- **You may be able to stratify the data by an attribute of the process or attribute of the corresponding work product**
  - E.g., different styles of peer reviews, peer reviews of different types of work products



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Hearing Voices

- **Voice of the process**
  = the natural bounds of process performance
- **Voice of the customer**
  = the goals established for the product/process performance
- **Voice of the business**
  = process performance needed to be competitive

- **Process capability may be determined for the**
  - Organization
  - Product line
  - Project
  - Individual
- **Typically, the higher the level of analysis, the greater the variation**

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Common Challenges for Engineering

- Data are often discrete rather than continuous, e.g., defects
- Observations often are scarce
- Processes are aperiodic
- Size of the the object often varies, e.g., software module
- Data distributions may not be normal

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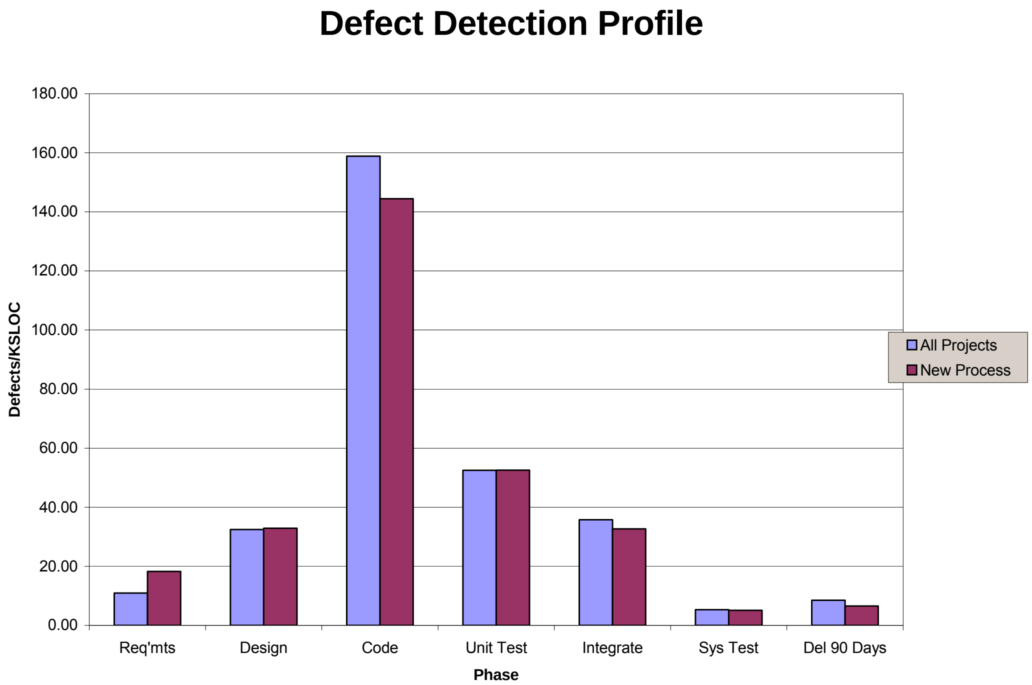
How Do I Address These Challenges?

- **Employ control chart types that specifically deal with discrete data distributions, e.g., *u*-charts and *p*-charts**
- **Use control charts that compensate for widely variable areas of opportunity**
- **Transform non-normal continuous data to normal data before constructing a control chart**
- **Cross check control charts with hypothesis tests where few data points exist**

Typical Choices in Industry

- **Most customers care about:**
  - Delivered defects
  - Cost and schedule
- **So organizations try to predict:**
  - Defects found throughout the lifecycle
  - Effectiveness of peer reviews, testing
  - Cost achieved/actual (Cost Performance Index – CPI)
  - Schedule achieved/actual (Schedule Performance Index – SPI)



Process performance
- **Process measures** (e.g., effectiveness, efficiency, speed)
- **Product measures** (e.g., quality, defect density).

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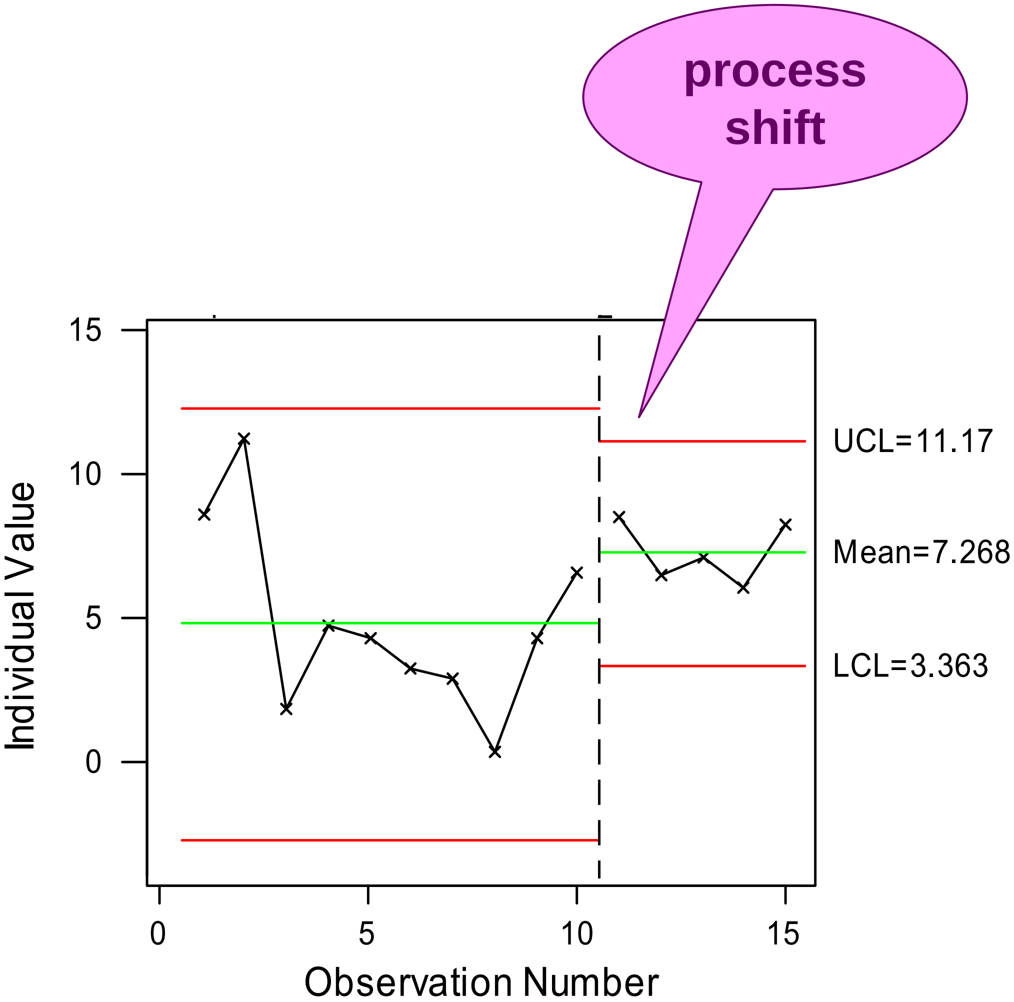
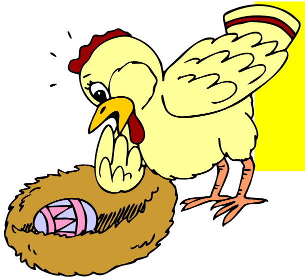
How Can High Maturity Help?

- **By measuring both the mean and variation, the project/ organization can assess the full impact of an "improvement"**
- **Can focus on reducing the variation (making the process more predictable)**
  - Train people on the process
  - Create procedures/checklists
  - Strengthen process audits
- **Can focus on increasing the mean (e.g., increase effectiveness, efficiency, etc.)**
  - Train people
  - Create checklists
  - Reduce waste and re-work
  - Replicate best practices from other projects
- **Can do both**



What Can a Level 4 Organization/Project Do?

- **Both can:**
  - Determine whether processes are behaving consistently or have stable trends (i.e., are predictable)
  - Eliminate special causes of variation
  - Identify processes that show unusual (e.g., unpredictable) behavior
  - Identify the implementation of a process which performs best
- **The organization can:**
  - Characterize the process performance of the organization's standard process
  - Develop models to predict process performance
- **The organization's projects can:**
  - Use this data to decide how to tailor the organization's standard process
  - Statistically manage selected subprocesses to achieve project quality and process objectives



Would your organization/projects find this valuable?

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What Does Level 5 Add?

Builds on Level 4 capabilities

Causal Analysis

- Both the project and organization can better determine cause and effect relationships
- This can be used to focus process improvements and preventive actions

Level 5

Organizational Innovation & Deployment

- Goals are quantitative (e.g., reduce variation by X%, reduce mean by Y%)
- Incremental improvements
- Innovative improvements - cause a major shift in process capability
- Potential improvements are analyzed to estimate costs and impacts (benefits)
- Improvements are piloted to ensure success
- Improvements are measured in terms of variation and mean

Level 3

Organizational Process Focus

- Goals are qualitative (e.g., get better)
- The effects of the improvements are not estimated or measured

How Does Level 4 & 5 Benefit the Customer?

Organizational process performance	More accurate estimates
Quantitative project management	Problem behaviors are recognized faster, enabling quicker resolution
Organizational innovation and deployment	The project benefits from improvements found and proven on other projects
Causal analysis	The project fixes the source of defects to prevent future defects

Better Products and Services Produced Faster And Cheaper

"How Does How Does High Maturity Benefit the Customer", R. Hefner, Systems & Software Technology Conference,. 2005

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  - Lessons Learned
  - Links to Six Sigma

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The Project Manager's Dilemma at Level 3

I want to use the organization's standard process, but…

… Does it's performance and quality meet my customer's expectations?

… If not, how should I tailor the process?

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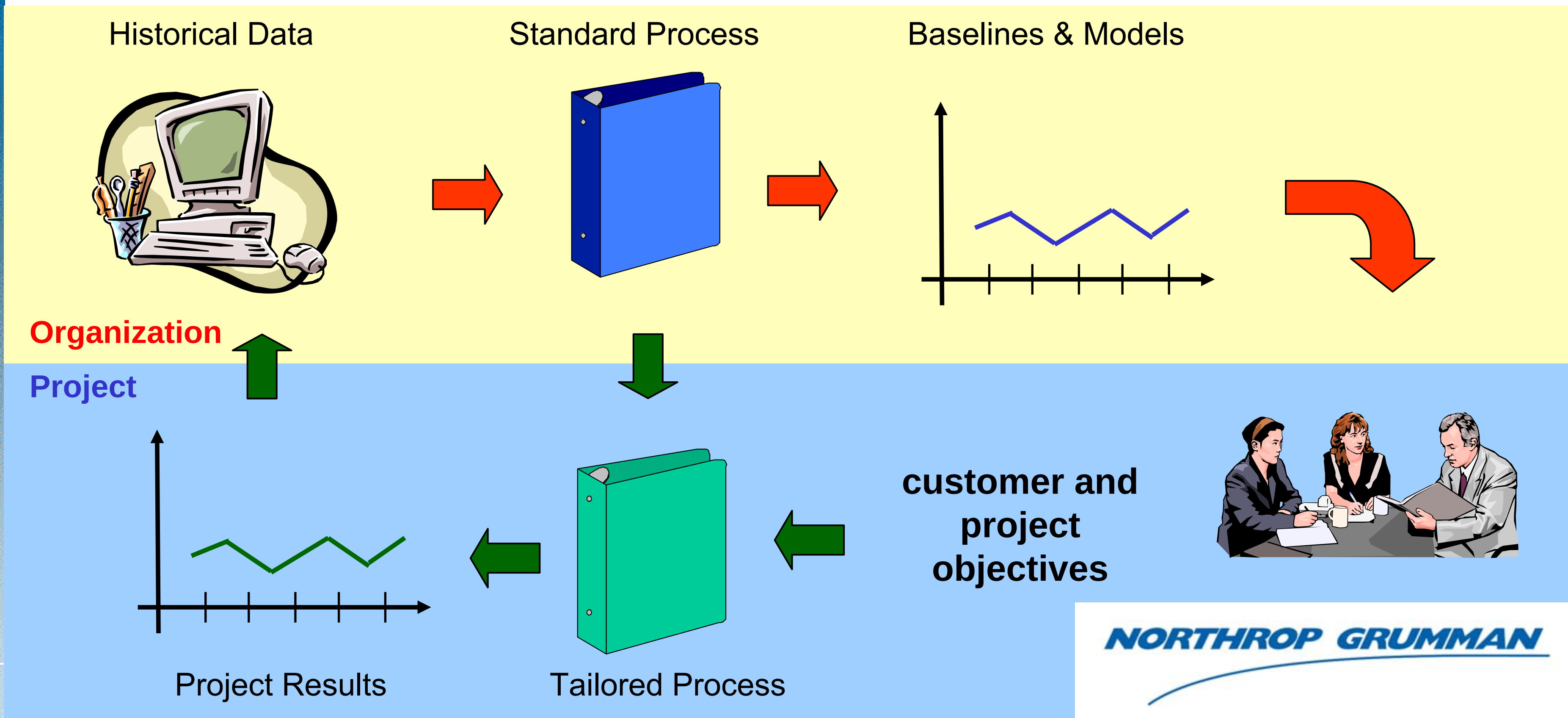
What Should the Organization Do to Help the Project Manager?

- Characterize the performance of the organization’s standard process statistically
- Develop models to help a project manager determine the performance they would be likely to get by using the standard organizational process model, given their project’s characteristics



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Organizational Process Performance

SG 1 Establish Performance Baselines and Models

Baselines and models that characterize the expected process performance of the organization's set of standard processes are established and maintained.

SP 1.1 Select Processes

Select the processes or process elements in the organization's set of standard processes that are to be included in the organization's process performance analyses.

SP 1.2 Establish Process Performance Measures

Establish and maintain definitions of the measures that are to be included in the organization's process performance analyses.

SP 1.3 Establish Quality and Process-Performance Objectives

Establish and maintain quantitative objectives for quality and process performance for the organization.

SP 1.4 Establish Process Performance Baselines

Establish and maintain the organization's process performance baselines.

SP 1.5 Establish Process Performance Models

Establish and maintain the process performance models for the organization's set of standard processes.

Selected subprocesses, NOT the whole process

Objectives deal with eliminating sources of variation, not setting "stretch" goals

The organization meets these goals by modifying the standard process, not driving the projects

Baselines characterize the "voice of the process", based on the existing historical data

- What is the current mean and variation?

May need to subgroup the data

Models allow projects to estimate their quantitative performance based on the historical data of other projects executing the process

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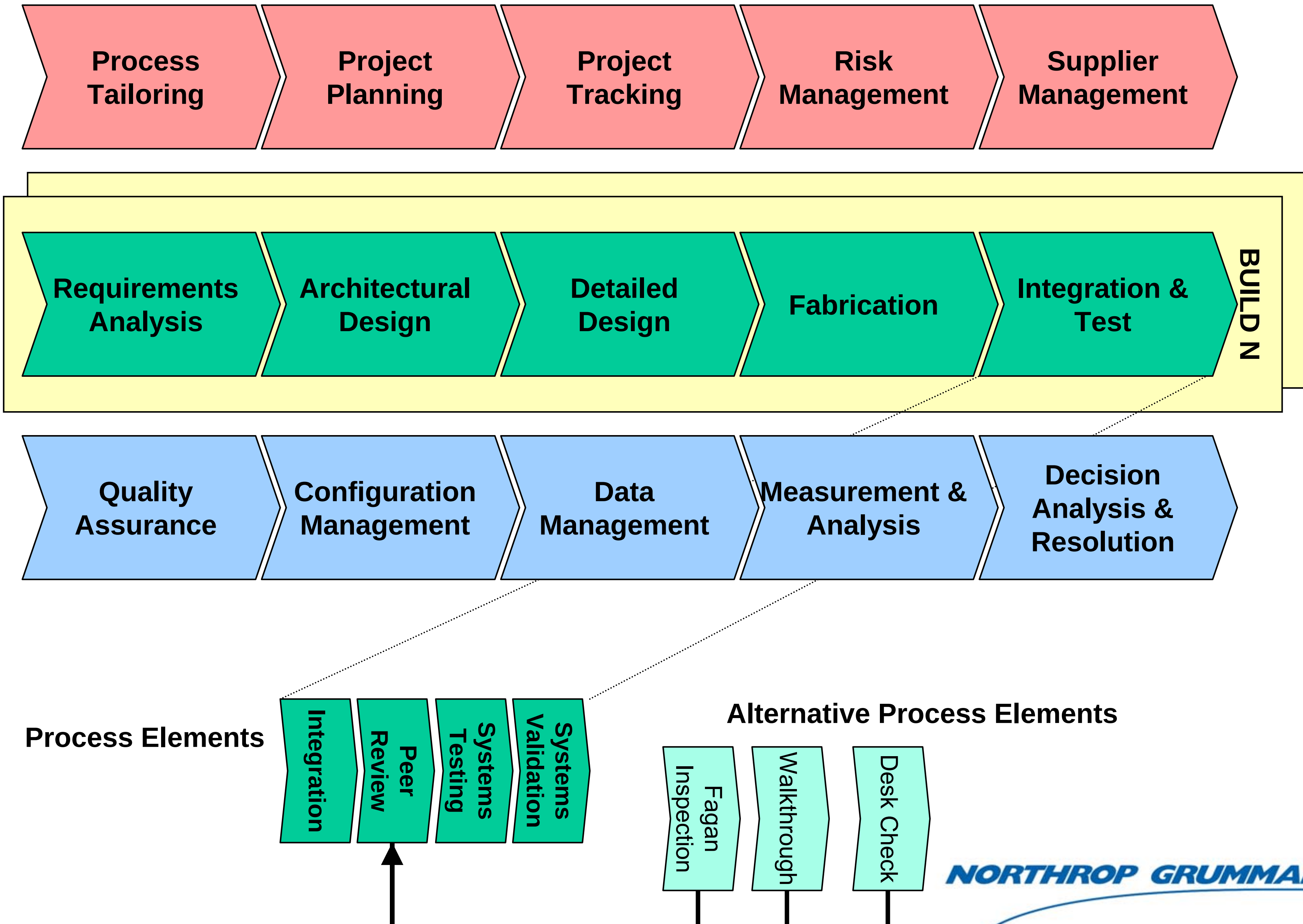
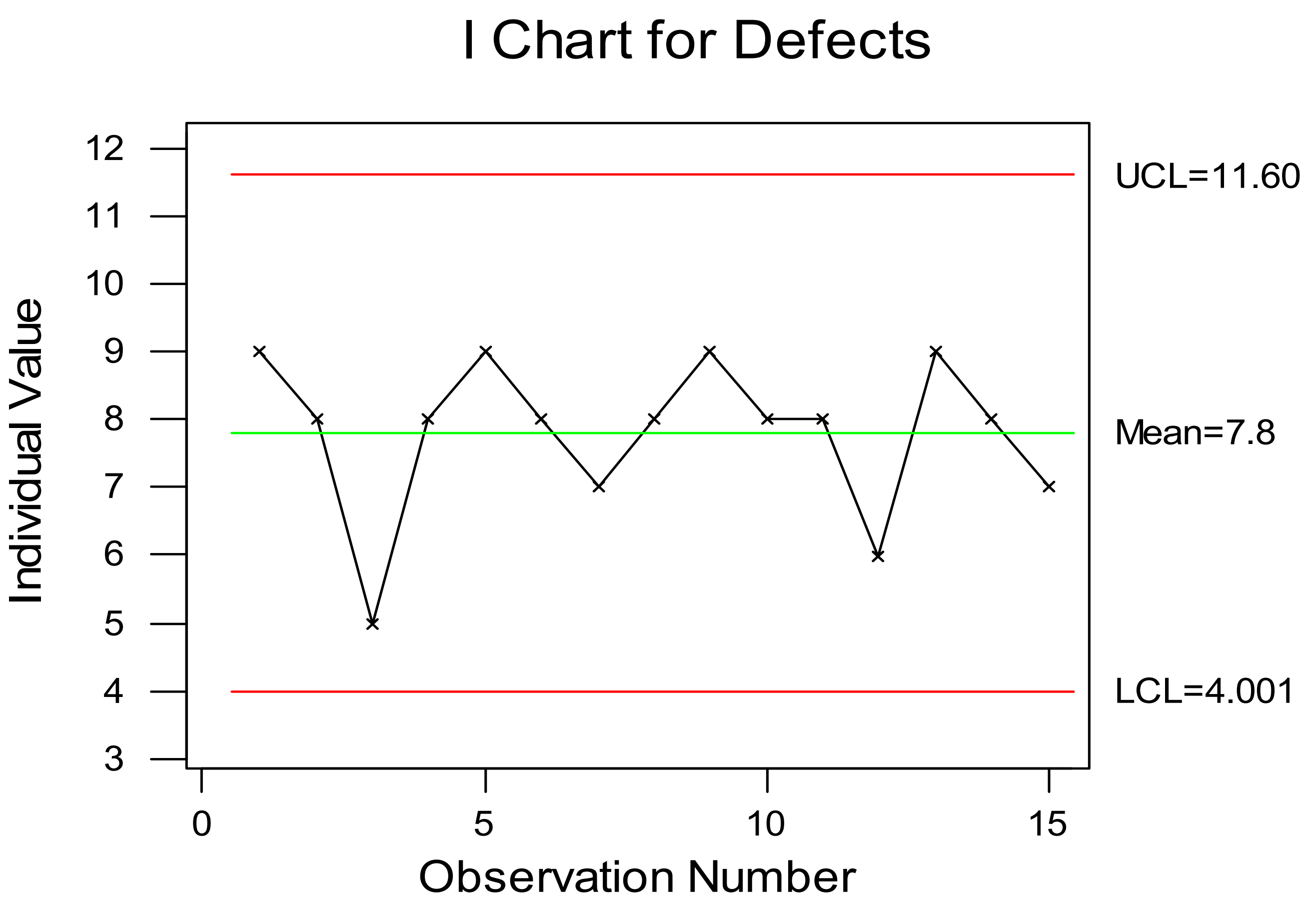
Process Architecture



Quantitative Baselines and Models

- **From this baseline (and model), what would you predict the next peer review to produce in terms of defects/KSLOC?**
- **What other models could be developed to help predict?**



The Project Manager’s Challenge at Level 4

I understand the capabilities of the organization’s standard process, but…

… What are the project’s quality and process performance objectives?

… How should I tailor the process?

… What project subprocesses do I need to quantitatively manage?

Quantitative Project Management (Goal 1)

SG 1 Quantitatively Manage the Project

The project is quantitatively managed using quality and process-performance objectives.

SP 1.1 Establish the Project's Objectives

Establish and maintain the project's quality and process performance objectives.

SP 1.2 Compose the Defined Process

Select the subprocesses that compose the project's defined process based on historical stability and capability data.

SP 1.3 Select the Subprocesses that Will Be Statistically Managed

Select the subprocesses of the project's defined process that will be statistically managed.

SP 1.4 Manage Project Performance

Monitor the project to determine whether the project's objectives for quality and process performance will be satisfied, and identify corrective action as appropriate.

Quality: defect levels of key work products or deliverables

Process: productivity, efficiency, effectiveness of the project's processes

Rationale for how the project tailored the organization's standard process, in order to meet their quality & process performance objectives
- E.g., adding procedures to reduce variation

Assumes the standard process includes subprocesses to select from

Only some subprocesses selected for statistical management
- Need not be the same as those selected by the organization, or other projects

Monitoring against the objectives established in SP 1.1

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Outer Loop

SP 1.1 Establish the Project's Objectives

Establish and maintain the project's quality and process performance objectives.

SP 1.3 Select the Subprocesses that Will Be Statistically Managed

Select the subprocesses of the project's defined process that will be statistically managed

SP 1.4 Manage Project Performance

Monitor the project to determine whether the project's objectives for quality and process performance will be satisfied, and identify corrective action as appropriate.

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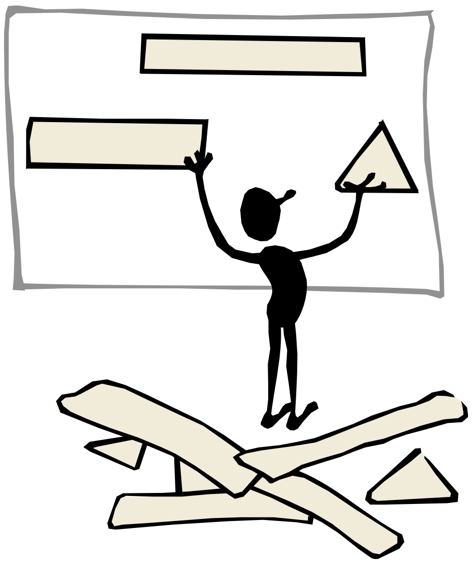
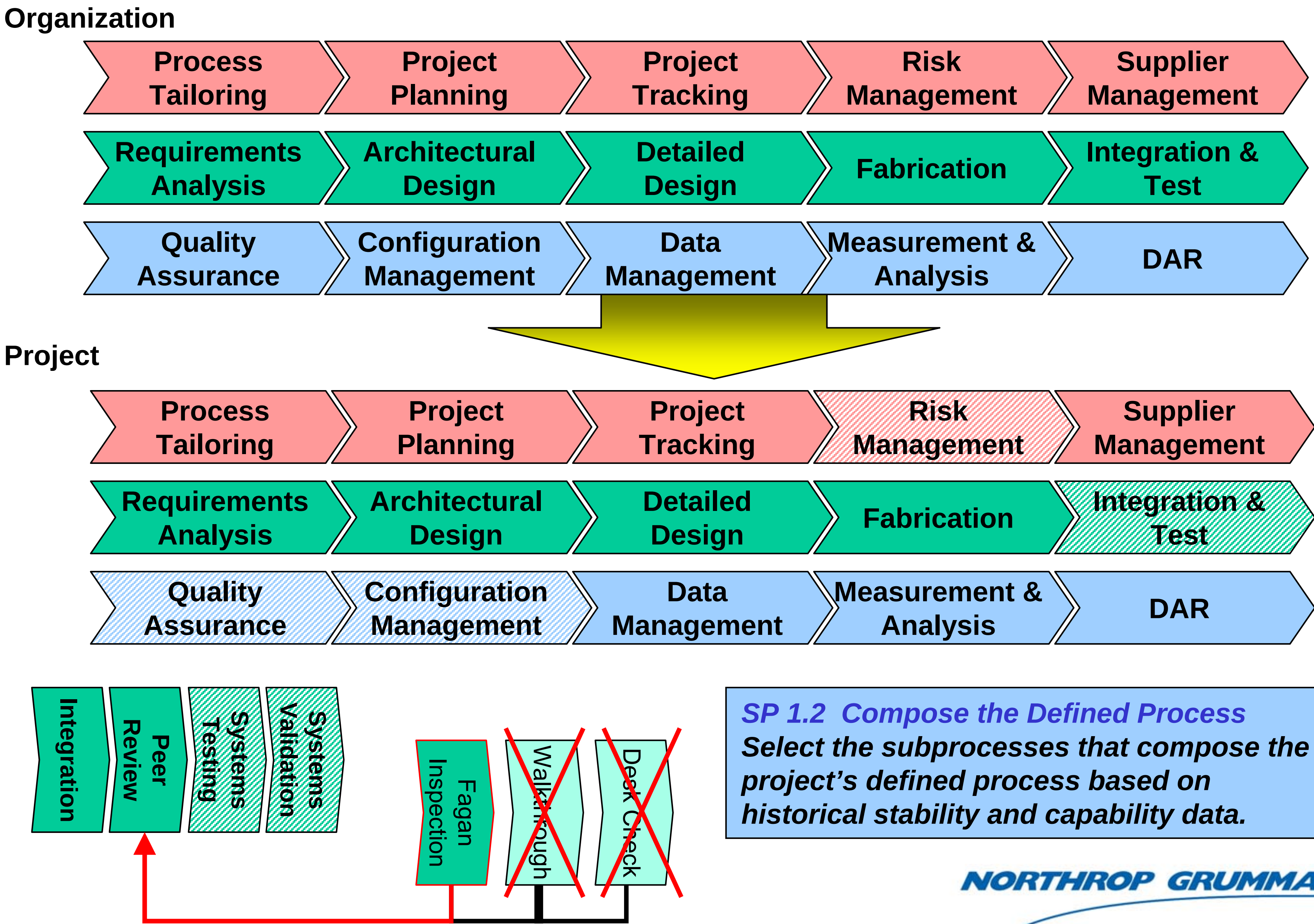
Selecting Subprocesses to be Statistically Managed

SP 1.3 Select the Subprocesses that Will Be Statistically Managed
Select the subprocesses of the project's defined process that will be statistically managed

- **Which processes do you need to be stable (predictable) in order to achieve your project's objectives?**
  - For these, eliminate special causes, characterize the process, and predicatively manage
- **The time needed to perform this practice is long and often unpredictable**
  - Many processes can not be made predictable
- **Example – objectives for delivered defects**
  - Defect detection (peer review, unit testing, system testing)
  - Defect insertion (requirement definition, architecture, design, integration)



Tailoring



SP 1.2 Compose the Defined Process
Select the subprocesses that compose the project's defined process based on historical stability and capability data.

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Quantitative Project Management (Goal 2)

SG 2 Statistically Manage Subprocess Performance
The performance of selected subprocesses within the project's defined process is statistically managed.

SP 2.1 Select Measures and Analytic Techniques
Select the measures and analytic techniques to be used in statistically managing the selected subprocesses.

SP 2.2 Apply Statistical Methods to Understand Variation
Establish and maintain an understanding of the variation of the selected subprocesses using the selected measures and analytic techniques.

SP 2.3 Monitor Performance of the Selected Subprocesses
Monitor the performance of the selected subprocesses to determine their capability to satisfy their quality and process performance objectives, and identify corrective action as necessary.

SP 2.4 Record Statistical Management Data
Record statistical and quality management data in the organization's measurement repository.

Type of analysis to be performed (e.g., control charts)

Key is understanding variation in the selected subprocesses (e.g., be able to compute standard deviation), NOT just metrics

Given the stability and variation in the subprocesses, will we be able to meet our project-level quality and process performance objectives?

This data is used to help select subprocesses in tailoring (SP 1.2)

Inner Loop

SP 1.1 Establish the Project's Objectives
Establish and maintain the project's quality and process performance objectives.

SP 1.3 Select the Subprocesses that Will Be Statistically Managed
Select the subprocesses of the project's defined process that will be statistically managed

SP 2.2 Apply Statistical Methods to Understand Variation
Establish and maintain an understanding of the variation of the selected subprocesses using the selected measures and analytic techniques.

SP 2.3 Monitor Performance of the Selected Subprocesses
Monitor the performance of the selected subprocesses to determine their capability to satisfy their quality and process performance objectives, and identify corrective action as necessary.

SP 1.4 Manage Project Performance
Monitor the project to determine whether the project's objectives for quality and process performance will be satisfied, and identify corrective action as appropriate.

Sample Measures for Quantitative Analysis

- Time between failures
- Critical resource utilization
- Number and severity of defects in the released product
- Number and severity of customer complaints concerning the pro-vided service
- Number of defects removed by product verification activities (per-haps by type of verification, such as peer reviews and testing)
- Defect escape rates
- Number and density of defects by severity found during the first year following product delivery or start of service
- Cycle time
- Amount of rework time
- Requirements volatility (i.e., number of requirements changes per phase)
- Ratios of estimated to measured values of the planning parameters (e.g., size, cost, and schedule)
- Coverage and efficiency of peer reviews (i.e., number/amount of products reviewed compared to total, number of defects found per hour)
- Test coverage and efficiency (i.e., number/amount of products tested compared to total, number of defects found per hour)
- Effectiveness of training (i.e., percent of planned training completed and test scores)
- Reliability (i.e., mean time-to-failure usually measured during inte-gration and systems test)
- Percentage of the total defects inserted or found in the different phases of the project life cycle
- Percentage of the total effort expended in the different phases of the project life cycle
- Profile of subprocesses under statistical management (i.e., number planned to be under statistical management, number currently being statistically managed, and number that are statistically stable)
- Number of special causes of variation identified

Source: Interpreting the CMMI, Margaret Kulpa and Kent Johnson

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New Questions at Level 4

- What characteristics of the organizational standard process would be useful to understand?
- Which subprocesses would be useful to understand, for predictive purposes?
- Are these subprocesses predictable (stabilizable)?
- What data should the organization collect?
- To what level of detail should the organizational standard process go?
- What differences in project subprocesses are permissible? How do they impact the historical data?

What Does Level 5 Add to the Project / Organization?

- **Casual Analysis & Resolution**
  - Identify and analyze causes of defects and other ~~problems~~ effects
  - Take specific actions to remove the causes

- **The project may take actions to prevent the occurrence of those types of defects and problems in the future**
- **Most projects use CAR-type methods and tools at Level 4, to identify and eliminate special cause variations, i.e., to stabilize the processes**
- **At Level 5, CAR is used to eliminate common cause variation**

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Causal Analysis & Resolution

SG 1 Determine Causes of Defects

Root causes of defects and other problems are systematically determined.

SP 1.1 Select Defect Data for Analysis

Select the defects and other problems for analysis.

SP 1.2 Analyze Causes

Perform causal analysis of selected defects and other problems and propose actions to address them.

Can apply to any cause and effect relationship, not just defects

Typically, projects will establish a list of potential areas in which to apply CAR, and select some from that list

Determine cause and effect (e.g., fishbone diagram, brainstorming) and potential improvement action list

Select some actions on the list to implement

SG 2 Address Causes of Defects

Root causes of defects and other problems are systematically addressed to prevent their future occurrence.

SP 2.1 Implement the Action Proposals

Implement the selected action proposals that were developed in causal analysis.

SP 2.2 Evaluate the Effect of Changes

Evaluate the effect of changes on process performance.

SP 2.3 Record Data

Record causal analysis and resolution data for use across the project and organization.

Implemented for each selected action
- Evidence will provide samples

Measures the effect of the change

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Organizational Innovation and Deployment

SG 1 Select Improvements
Process and technology improvements that contribute to meeting quality and process-performance objectives are selected.

SP 1.1 Collect and Analyze Improvement Proposals
Collect and analyze process- and technology-improvement proposals.

SP 1.2 Identify and Analyze Innovations
Identify and analyze innovative improvements that could increase the organization's quality and process performance.

SP 1.3 Pilot Improvements
Pilot process and technology improvements to select which ones to implement.

SP 1.4 Select Improvements for Deployment
Select process- and technology-improvement proposals for deployment across the organization.

SG 2 Deploy Improvements
Measurable improvements to the organization's processes and technologies are continually and systematically deployed.

SP 2.1 Plan the Deployment
Establish and maintain the plans for deploying the selected process and technology improvements.

SP 2.2 Manage the Deployment
Manage the deployment of the selected process and technology improvements.

SP 2.3 Measure Improvement Effects
Measure the effects of the deployed process and technology improvements.

Innovative improvements are likely to significantly change the process/quality performance

Where appropriate, a proposed improvement should be piloted

Innovative improvements often require a phase-in approach

The effects should be measured quantitatively (as opposed to qualitatively in OPF), i.e. process shift

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Achieving Levels 4 and 5 is Less Predictable

- **The time it takes to achieve Levels 2 and 3 is driven by the resources available**
  - Learn/implement new project practices
  - Create organizational assets - policies, processes, training, etc.
  - Practices are first performed; *effectiveness is improved over time*
- **The time it takes to achieve Levels 4 and 5 is driven by the ability to stabilize processes**
  - Choosing processes that can be stabilized
  - Establishing the right metrics and methods
  - Collecting enough data
  - *Effectiveness is required to perform the practices*

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Lessons Learned

Based on 20 Northrop Grumman CMMI Level 5 organizations

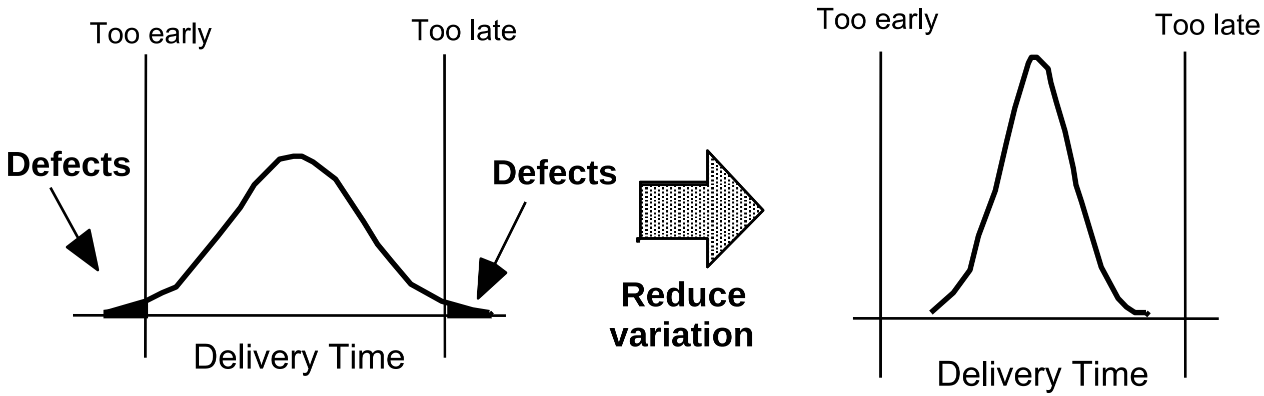
- **Level 3 metrics, measurement processes, and goal setting are generally inadequate for Levels 4 and 5**
  - Better definitions of the measures
  - Lower level metrics of lower level subprocesses
  - Stratifying the data properly
- **When operating at Level 3, it is difficult to predict the measurement improvements needed**
  - Trying to understand and stabilize the key subprocesses will naturally drive you to the right metrics
- **Projects have different quality and process performance needs, and should select different subprocesses to quantitatively manage**
  - This will also slow adoption, and complicate the organizational baselines and models
- **Six Sigma is an enabler for higher maturity**
  - Focus on data, measurement systems, process improvement
  - Tying improvements to business goals
  - Tools and methods support the level 4/5 analysis tasks

What is Six Sigma?

- **Six Sigma is a management philosophy based on meeting business objectives by striving for perfection**
  - A disciplined, data-driven methodology for decision making and process improvement
- **Six Sigma consists of several integrated methods:**
  - Process Management
  - Voice of the Customer
  - Change Management
  - Tools for Measuring Variation and Change
  - Business Metrics
- **Leading-edge companies are applying Six Sigma to engineering work**

Importance of Reducing Variation

- **To increase process performance, you have to decrease variation**



Spread of variation too wide compared to specifications

Spread of variation narrow compared to specifications

- **Less variation means**
  - Greater predictability in the process
  - Less waste and rework, which lowers costs
  - Products and services that perform better and last longer
  - Happier customers

A Typical Six Sigma Project in Engineering

- Customers express concern that software defects are causing frequent failures in the field
- A Six Sigma team is formed to scope the problem, collect data, and determine the root cause
- The team's analysis of the data determines that poorly understood interface requirements account for 90% of the problems in the field
- The interface problems are corrected
- The organization's requirements solicitation process is modified to ensure future projects do not encounter similar problems

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DMAIC Process Steps

DEFINE	**Set project goals and objectives**
MEASURE	**Narrow range of potential causes and establish baseline capability level**
ANALYZE	**Evaluate data/information for trends, patterns, causal relationships and "root causes“**
IMPROVE	**Develop, implement and evaluate solutions targeted at identified root causes**
CONTROL	**Make sure problem stays fixed and new methods can be further improved over time**

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How Six Sigma Helps Level 4-5 Organizations

- **Six Sigma provides specific methods and tools for:**
  - Quantitative process management of Level 4
  - Causal Analysis and Resolution of Level 5
- **Six Sigma projects provide a mechanism for selecting and implementing improvements**
  - Addresses Organizational Innovation and Deployment
  - Can extend beyond Level 5

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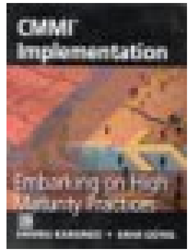

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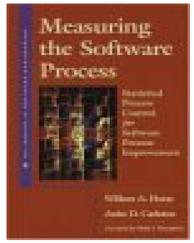

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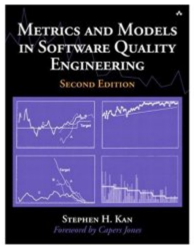

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