Evolving a Measurement Program for Systems and Software Engineering Process Improvement

CMMI 2003
Denver, Colorado

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Measurement and Analysis

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Measurement and Analysis Overview

- A measurement initiative involves the following:
  - Specifying the objectives of measurement and analysis such that they are aligned with established information needs and business objectives
  - Defining the measures to be used, the data collection process, the storage mechanisms, the analysis processes, the reporting processes, and the feedback processes
  - Implementing the collection, storage, analysis, and presentation of the data
  - Providing objective results that can be used in making business judgments and taking appropriate corrective actions

Establish Measurement Objectives

- Measurement objectives
  - Document the purposes for which measurement and analysis is done (GQM)
  - Specify the kinds of actions that may be taken based on the results of the data analyses
  - Continually ask the question – what value will this measurement be to those people who will be asked to supply the raw measurement data and who will receive the analyzed results
  - Involve the end users of the measurement and analysis results in setting measurement objectives whenever possible
  - Maintain traceability of the proposed measurement objectives to the information needs and business objectives

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Specify Measures

- Identify candidate measures based on documented objectives and refine into precisely defined, quantifiable measures
- Define how data can and will be derived from other measures
- Examples of Commonly Used Derived Measures
  - Defect density
  - Peer review coverage
  - Reliability measures

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Specify Data Collection and Storage Procedures

- Specify how to collect and store the data for each required measure
  - Make explicit specifications of how, where, and when the data will be collected
  - Develop procedures for ensuring that the data collected is valid data
  - Ensure that the data is stored such that it is easily accessed, retrieved, and restored as needed

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Specify Analysis Procedures

- Define the analysis procedures in advance
- Ensure that the results that will be fed back are ***understandable*** and ***easily interpretable***
  - Collecting data for the sake of showing an assessor the data is worthless
  - Showing how it can be used to manage and control the project is what counts

Collect Measurement Data

- Collect the measurement data as defined, at the points in the process that were agreed to, according to the time scale established
- Generate data for derived measures
- Perform integrity checks as close to the source of the data as possible

Analyze the Measurement Data

- Conduct the initial analyses
- Interpret the results and make preliminary conclusions from explicitly stated criteria
- Conduct additional measurement and analyses passes as necessary to gain confidence in the results
- ***Review the initial results with all stakeholders***
  - Prevents misunderstandings and rework
- Improve measurement definitions, data collection procedures, analyses techniques as needed to ensure meaningful results that support business objectives

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Store the Measurement Data and Analyses Results

- The stored information should contain or reference the information needed to:
  - Understand the measures
  - Assess them for reasonableness and applicability
- The stored information should also:
  - Enable the timely and cost effective future use of the historical data and results
  - Provide sufficient context for interpretation of the data, measurement criteria, and analyses results

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Communicate the Measurement Results

- Keep the relevant stakeholders up-to-date about measurement results on a timely basis
- Follow up with those who need to know the results
  - Increases the likelihood that the reports will be used
- Assist the relevant stakeholders in understanding and interpreting the measurement results

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Measurement and Analysis Group

- Consider creating a measurement group that is responsible for supporting the Measurement and Analysis activities of multiple projects

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Measurement and Analysis Tools

- Incorporate tools used in performing Measurement and Analysis activities such as:
  - Statistical packages
  - Database packages
  - Spreadsheet programs
  - Graphical packages
  - Packages that support data collection over networks and the internet

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Measurement and Analysis Training

- Provide training to all people who will perform or support the Measurement and Analysis process
  - Data collection, analyses, and reporting processes
  - Measurement tools
  - Goal-Question-Metric Paradigm
  - How to establish measures
    - how to determine efficiency and effectiveness
  - Quality factors measures (e.g., maintainability, expandability)
  - Basic and advanced statistical techniques

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Basic Measures

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Basic Measures

- ***Estimate*** Size and/or Complexity - a relative level of difficulty or complexity should be assigned for each size attribute
- Examples of attributes to estimate for Systems Engineering include:
  - Number of logic gates
  - Number of interfaces
- Examples of size measurements for Software Engineering include:
  - Function Points
  - Lines of Code
  - Number of requirements

Basic Measures - 2

- ***Determine*** effort and cost – use historical data or models
- ***Establish*** the project's schedule based on the size and complexity estimations
- Include, or at least consider, infrastructure needs such as critical computer resources
- Identify risks associated with the cost, resources, schedule, and technical aspects of the project
- Control data (various forms of documentation) required to support a project in all of its areas.

Basic Measures – 3

- Identify the knowledge and skills needed to perform the project according to the estimates
- Select and implement methods for providing the necessary knowledge and skills
  - Training (Internal and External)
  - Mentoring
  - Coaching
  - On-the-job application of learned skills
- Monitor staffing needs – based on effort required and the necessary knowledge and skills to achieve the defined tasks

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Basic Measures - 4

- Involve relevant stakeholders throughout the product lifecycle
- Track technical performance (Completion of activities and milestones against the schedule Example:
  - Product components designed, constructed, unit tested and integrated
- Compare actual milestones completed vs. established commitments
- Monitor commitments and critical dependencies against those documented in the project plan

Basic Measures - 5

- Track quality – Problems/Defects (open/closed by product/activity)
  - Problems and defects are direct contributors to the amount of rework that must be performed—a significant cost factor in development and maintenance

Effectiveness of Processes

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Effectiveness of Processes

- In addition to defining the processes that we wish to follow on our project, we need to ensure we are following them and we should be able to determine if the processes are working for us the way we expected them to
  - How well are the processes working?

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Requirements Management – Effectiveness Example

- Number of change requests per month compared with the original number of requirements for the project
  - Critical change requests
  - Intermediate change requests
  - Nice to have change requests
- Time spent on change requests up until a Y/N decision is given from the Senior Contract group
- Number and size of critical change requests that arise after the requirements phase has been completed

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Set of Standard Organizational Processes

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Importance of an Organizational View of Processes

- Builds a common vocabulary
- Allows others to anticipate behavior and be more proactive in their interactions
- Allows the organization to measure a controlled set of processes to gain economy of scale
- Trends can be seen and predictability can be achieved
- Process performance baselines can be developed to support quantitative management later

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Organizational Measurement Repository

- Develop an organization measurement repository - include:
  - Product and process measures that are related to the organization's set of standard processes
  - The related information needed to **understand and interpret** the measurement data and asses it for reasonableness and applicability
- Develop operational definitions for the measures to specify the point in the process where the data will be collected and for the procedures for collecting valid data

Slightly More Advanced Measures

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Peer Reviews

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Peer Review Measures

- Optimum Checking Rate (e.g., Number of pages to be checked per hour)
- Logging Rate (e.g., Number of major and defects logged per hour)
- Number of Major and Minor Defects
- Effectiveness - Number of Major Defects found in this stage compared to the total number of defects found so far

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Testing

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Defects Discovered During Testing

- Effectiveness - Number of Major defects found in a particular testing phase or instantiation of a testing phase compared to the total number of defects found during testing
- Number of defects projected to escape from the current testing phase

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Test Coverage

- Statement coverage measures whether each executable statement is encountered
- Block coverage is the same as statement coverage except that the unit of code measured is each sequence of non-branching statements
- Decision coverage measures whether boolean expressions tested in control structures (such as if-statements or while-statements) evaluated to both true and false
- Condition coverage measures the true or false outcome of each boolean sub-expression

Test Coverage - 2

- Function Coverage
  - Measures whether you invoked each function or procedure
- Call Coverage
  - Measures whether you executed each function call
  - Based on the idea that faults commonly occur in interfaces between modules
- Loop Coverage
  - Measures whether you executed each loop body zero times, exactly once, and more than once
- Relational Operator Coverage
  - Measures whether boundary situations occur with relational operators (<, <=, >, >=)

Risk Management

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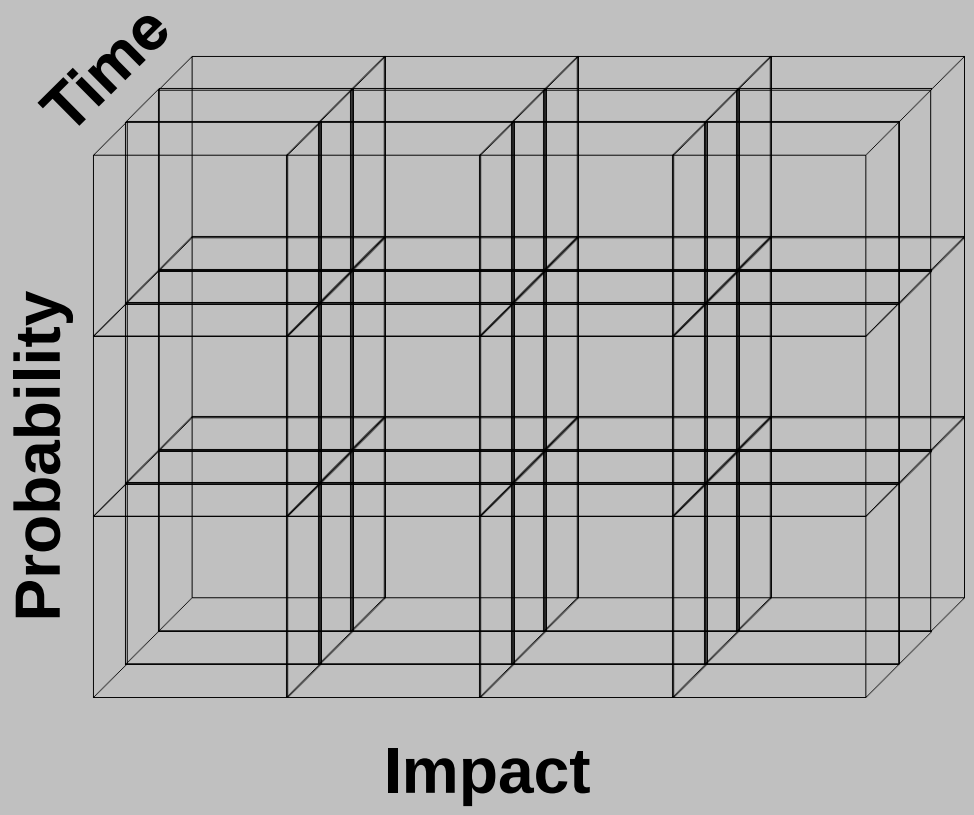
Prioritizing Risks

- Priorities are established by merging the information available into a three dimensional table



Prioritizing - 2

Probability: / *Impact:*	Probable	Possible	Unlikely
Catastrophic	Top	High	Serious
Critical	High	Serious	Medium
Marginal	Serious	Medium	Low
Negligible	Medium	Low	Bottom

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Prioritizing - 3

Time Frame:	Immediate	Short	Medium	Long
Top	1	2	3	4
High	2	3	4	5
Serious	3	4	5	6
Medium	4	5	6	7
Low	5	6	7	8
Bottom	6	7	8	9

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Quantitative Project Management

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Quantitative Management Concepts

- Quantitative Management is tied to the organization's strategic goals for product quality, service quality, and process performance
- When higher degrees of quality and performance are demanded, the organization and projects must determine if they have the ability to improve the necessary processes to satisfy the increased demands

Quantitative Management Concepts - 2

- Achieving the necessary quality and process performance objectives requires stabilizing the processes that contribute most to the achievement of the objectives
  - Cost
  - Schedule
  - Performance
  - Quality
- Assuming the technical requirements can be met, the next decision is to determine if it is cost effective
- Reducing process variation is an important aspect to quantitative management

Establish the Organization's Process Performance Baseline

- Process performance is a measure of the actual results achieved by following a process
- Measure the organization's process performance for the organization's set of standard processes at various levels including:
  - Individual processes (e.g., test case inspection element)
  - Sequence of connected processes
  - Processes for the complete lifecycle
  - Processes for developing individual work products

Establish the Organization's Process Performance Baseline - 2

- There may be several process performance baselines to characterize performance for subgroups of the organization – Examples include:
  - Product Line
  - Application domain
  - Complexity
  - Team size
  - Work product size

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Steps to Establish Project's Quality and Process Performance Objectives

- Identify the quality and process performance needs and priorities of the customer, end users, and other relevant stakeholders
  - Reliability
  - Maintainability and Expandability
  - Usability
  - Development cycle time
- Determine how quality and process performance will be measured

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Steps to Establish Project's Quality and Process Performance Objectives - 2

- Define and document measurable quality and process performance objectives for the project
- Examples of Quality Objectives
  - Mean time between failures
  - Critical resource utilization
- Examples of Process Performance Objectives
  - Percentage of defects removed by type of verification activity
  - Defect escape rates
  - Number and density of defects (by severity) found during the first year following product delivery
  - Rework time as a percentage of total project life-cycle time

Steps to Establish Project's Quality and Process Performance Objectives - 3

- Establish objectives for each life-cycle stage to track progress and predict achievement of project's objectives
- Establish criteria to identify which subprocesses are the main contributors to achieving the identified quality and process performance objectives and for which predictable performance is important

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Measures and Analytic Techniques

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Select Measures and Analytic Techniques

- Identify the measures that are appropriate for statistical management
- Examples of subprocess control measures include:
  - Ratios of estimated to measured values of the planning parameters
  - Coverage and efficiency of work product inspections
  - Test coverage and efficiency
  - Reliability, Maintainability, and Expandability
  - Percentage of the total defects inserted or found in the different stages of the lifecycle

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Select Measures and Analytic Techniques - 3

- Specify the operational definitions of the measures, their collection points in the subprocesses and how the measures will be validated
- State specific target measures or ranges to be met for each measured attribute of each selected process
- Set up the organizational support environment to support the collection and analysis of statistical measures
- Identify the appropriate statistical and quantitative management analysis techniques that are expected to be useful in statistically managing the selected subprocesses

Quantitative Tools

- Quantitative tools considered to be applicable to quantitative management or statistical process control
  - Scatter diagrams
  - Run charts
  - Cause-and-effect (fishbone) diagrams
  - Histograms
  - Bar charts
  - Pareto charts
  - Control charts

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Control Charts

- **Control charts** – techniques for quantifying process behavior
  - Allows a project team to monitor, control and improve process performance over time by studying variation and its source
  - Distinguishes special or assignable causes of variation from common causes of variation as a guide for management decision making
  - Serves as a tool for ongoing control of a process
  - Helps improve a process to perform consistently and predictably for higher quality, lower cost, and higher effective capacity
  - Defines the "Voice of the Process"

Brassard Michael, Ritter, Diane, .The Memory Jogger II, , 1994

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Control Charts - 2

- Control charts are most effective when they are used within the broader context of established goals and the activities performed to achieve those goals
- Classical control charts have a centerline and control limits on both sides of the centerline
- Both the centerline and the limits represent estimates that are calculated from a set of observations collected while the process is running
- The centerline and control limits cannot be assigned arbitrarily as they are intended to show what the process can actually do

Florac, W.A. & Carleton, A.D. Measuring the Software Process Addison-Wesley, 1999

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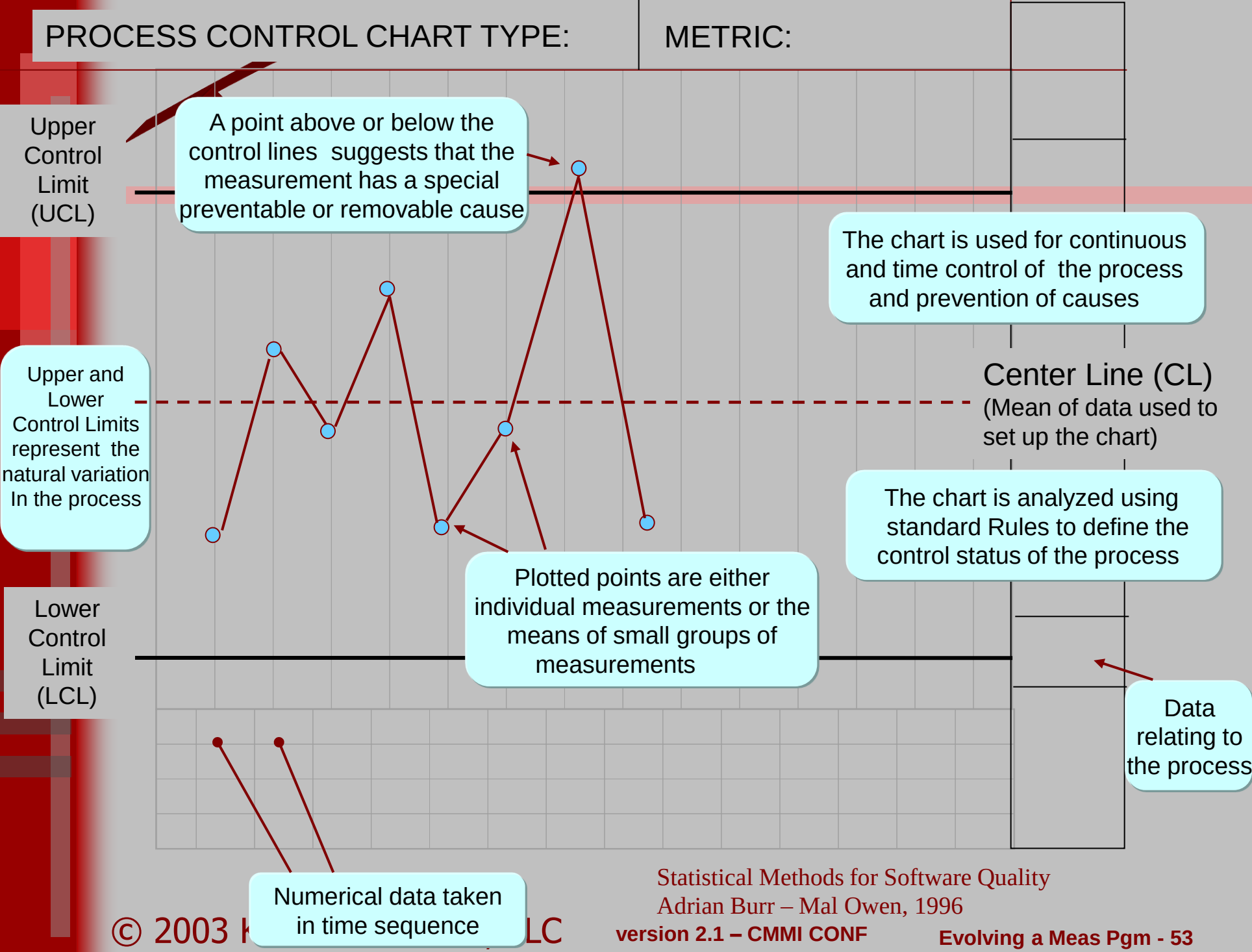
PROCESS CONTROL CHART TYPE:

METRIC:



Statistical Methods for Software Quality
Adrian Burr – Mal Owen, 1996

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Histograms

- **Histograms**
  - Allows a project team to take measurement data and display the distribution of the observed values
  - Show the frequencies of events that have occurred in ways that make it easy to compare distributions and see central tendencies
  - Illustrates quickly the underlying distribution of the data
  - Helps indicate if there has been a change in the process

Florac, W.A. & Carleton, A.D. Measuring the Software Process
Addison-Wesley, 1999

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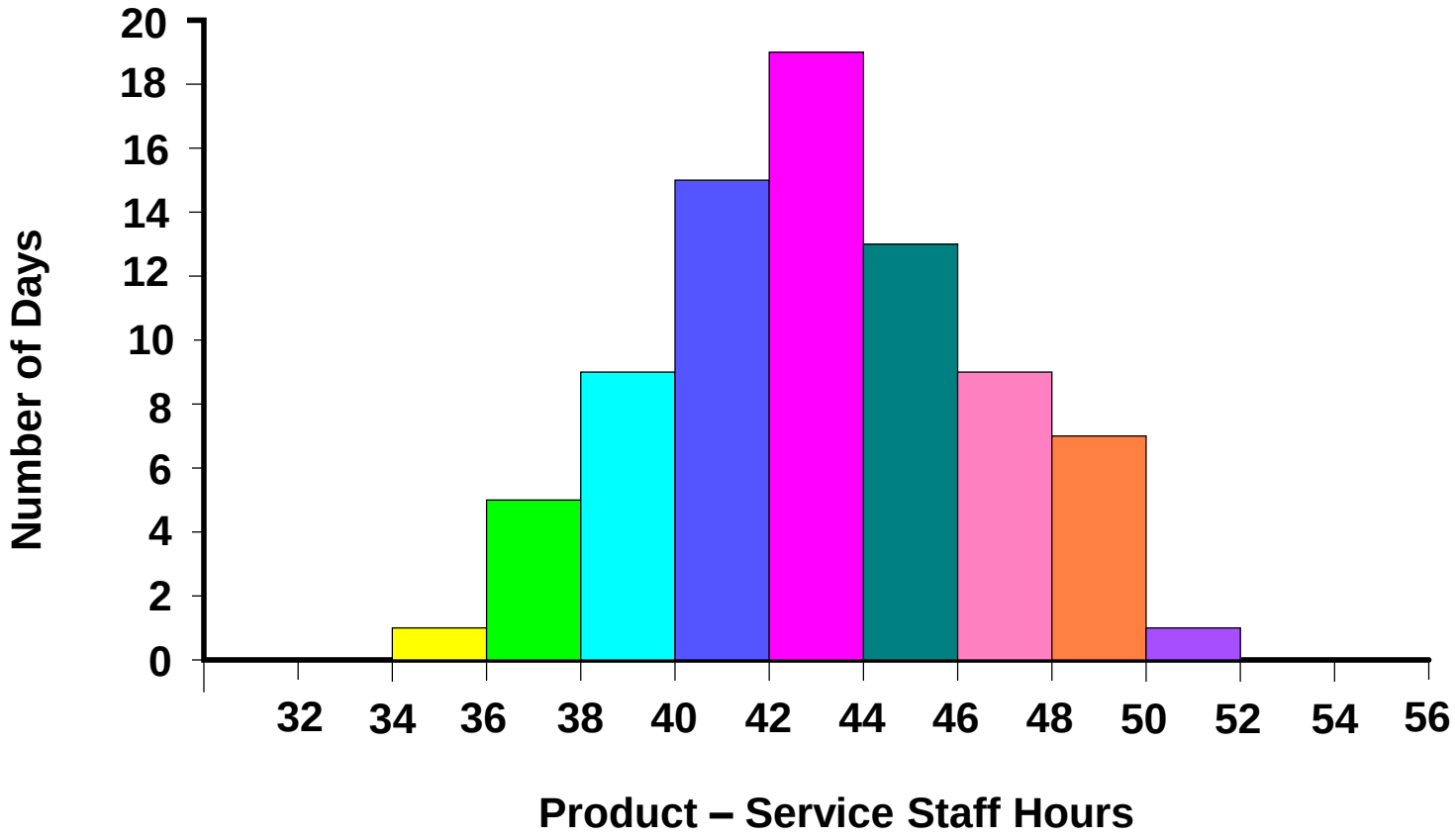
Histograms - 2

- **Histograms** - continued
  - Provides useful information for predicting future performance of the process
  - Helps answer the question "Is the process capable of meeting my customers requirements?"
  - Histograms are created by grouping the results into "cells" and then counting the number in each cell

Florac, W.A. & Carleton, A.D. Measuring the Software Process
Addison-Wesley, 1999

Histograms - 3



Applying Statistical Methods to Understand Variation

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Understanding Variation

- Understanding variation is achieved by collecting and analyzing process and product measures so that special causes of variation can be identified and addressed to achieve predictable performance
- All characteristics of processes and products display variation when measured over time
- Variation may be due to
  - Special or “assignable” causes of variation
  - Natural or common causes

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Summary

- Evolving a Measurement Program for Systems / Software Engineering Process Improvement includes:
  - Clearly defining the need for a measurement program
  - Establishing a measurement initiative with objectives that are aligned with established information needs and business objectives
  - Ensuring basic measures are included for planning, tracking, and taking corrective action as necessary
  - Incorporating process effectiveness measures
  - Establishing organizational standard processes

Summary - 2

- Establish and utilize measures such as peer review measures, testing measures, and risk management measures
- Evolve into project management based on a quantitative understanding of the organization's and project's defined processes

Thank You

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