Establishing a CMMI®-Compliant Measurement Program

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Achieving Software Excellence

Presentation Objective

- To present recommendations for establishing an effective measurement program compliant with SEI CMMI® Level 3 Process Area (PAs)
- Topics include:
  - Steps to developing an effective and practical measurement program
  - An overview of the SEI CMMI measurement requirements for the Level 2 and 3 PAs
  - A recommended set of measurements which comply with CMMI and promote process improvement

Scope

- Assumes audience has a working knowledge of CMMI
- Assumes measurement program is part of an organization's CMMI process improvement initiative
- Is focused on CMMI Staged Representation, Level 3 Process Areas (PAs) for a software organization
  - Not covered – Maturity levels 4 and 5
  - Not covered – Supplier Sourcing or IPPD
- Presents one example solution for establishing CMMI-based measurements
  - Many other approaches are possible
  - Approach is intended to be simple, practical, effective

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Establishing a Measurement Program

- Obtain the sponsorship and support of senior management
- Create an organizational measurements "guru" role and establish who will fill that role
- Use the Measurement and Analysis Process Area (PA) as a guide in establishing a measurement program
  - Agree on criteria for measurement selection and the business goals to support
  - Think through and address implementation requirements, e.g., data collection and reporting procedures, tools, training, etc.
  - Define and document measurements in a measurement definition document, e.g., a Measurement Plan

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Criteria for Selecting Measurements

- Measurements should support business goals and needs and will vary accordingly. For this presentation, assuming the following business needs:
  - Meeting cost, schedule and technical commitments
  - Managing and improving software quality
  - Managing and improving software productivity
  - Managing and improving process effectiveness through achieving CMMI Maturity Level 3
- The measurements must satisfy SEI CMMI Level 3 PAs' Specific and Generic Practices
- The measurements must be relatively easy to implement and be kept to an effective minimum number

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Criteria for Selecting Measurements*

- The measures must be robust, i.e., precise and relatively unaffected by minor changes in tools, methods, or product characteristics.
- The measures should suggest a norm, i.e., the meaning of a high or low value should be obvious.
- The measures should relate to specific product or process properties, e.g., errors, size, or resources expended.
- The measures should suggest an improvement strategy, i.e., should indicate what needs to be improved.
- The measures should be a natural result of the process. The effort to collect measurements should be kept to a minimum.
- The measures should be simple. They should not be difficult to explain.
- The measures should be both predictable and trackable, e.g., measures that provide planned versus actual comparisons.

*Source: **Watts Humphrey,** *Managing the Software Process*

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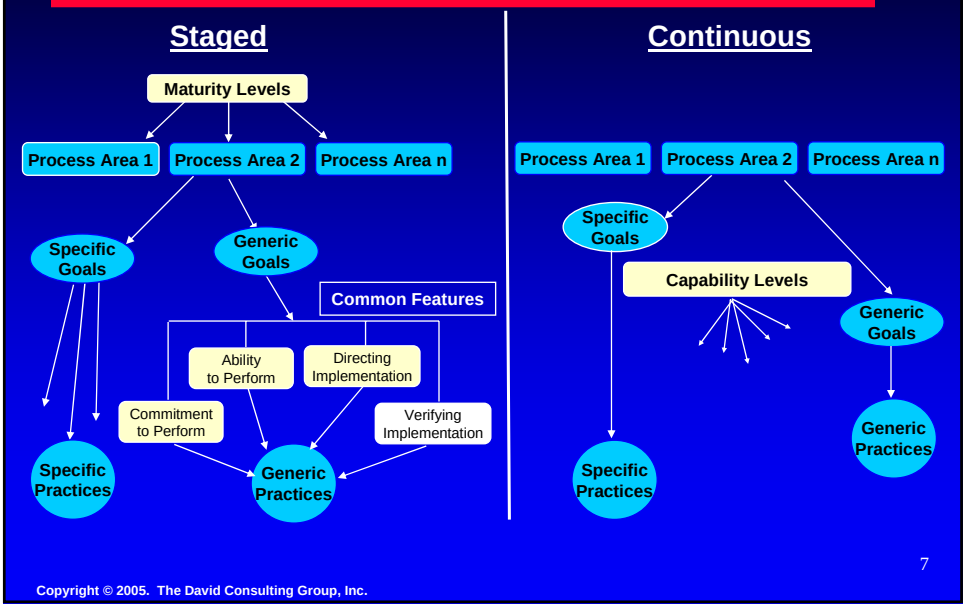
CMMI Model Structure



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CMMI Process Areas by Category & Maturity Level

Category	Level 2	Level 3	Level 4	Level 5 <----Maturity Level
Project Management	Project Planning Project Monitoring and Control Supplier Agreement Management	Integrated Project Management (IPM) or IPM for IPPD Risk Management Integrated Supplier Management (SS) Integrated Teaming (IPPD)	Quantitative Project Management	
Support	Measurement and Analysis Process and Product Quality Assurance Configuration Management	Decision Analysis and Resolution Organizational Environment for Integration (IPPD)		Causal Analysis and Resolution
Engineering	Requirements Management	Requirements Development Technical Solution Product Integration Verification Validation		
Process Management		Organizational Process Focus Organizational Process Definition Organizational Training	Organizational Process Performance	Organizational Innovation and Deployment

Measurement and Analysis PA

- SG 1 - Align Measurement and Analysis Activities
  - SP 1.1 - Establish Measurement Objectives
  - SP 1.2 - Specify Measures
  - SP 1.3 - Specify Data Collection and Storage Procedures
  - SP 1.4 - Specify Analysis Procedures
- SG 2 - Provide Measurement Results
  - SP 2.1 - Collect Measurement Data
  - SP 2.2 - Analyze Measurement Data
  - SP 2.3 - Store Data and Results
  - SP 2.4 - Communicate Results

Measurement and Analysis PA

- To address the MA SG 1 specific practices, create a measurement definition document, e.g., a "Measurement Plan"
  - Decide on format and content. Example contents:
    - Introduction
    - Measurement Objectives and Derivation
    - Measurement Specifications
    - Appendices
- To address the MA SG 2 specific practices, implement the Measurement Plan

Measurement and Analysis PA Measurement Specification Content

- Have one specification per measurement category (a logical grouping of related measurements)
  - Purpose and use
  - Collection requirements
    - Attribute data, e.g., department, project, date, etc.
    - Collected data – what and how
    - Derived measurements; calculation formula
  - Reporting requirements
    - Aggregation – covers usage at multiple management levels
    - Frequency
    - Presentation, e.g., chart type
    - Analysis
    - Storage
- Consider grouping specifications into related measurement uses, e.g., project-related and organizational

(See www.psmsc.com/SampleMeasures.asp for a sample measurement specification template and specification sheet examples for a number of measurements)

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Generic Goals and Practices

- Are applied to each Process Area
- Generic Goal (GG) 1 – Achieve the Specific Goals
  - Only applies to the Continuous Representation and Capability Level 1
- GG 2 – Institutionalize a Managed Process
  - Has 10 GPs
  - To achieve Maturity Level 2, required for all the Maturity Level 2 PAs
  - Applies to all Process Areas at Maturity Levels 3, 4, and 5 as well
- GG 3 – Institutionalize a Defined Process
  - Has 2 GPs
  - Also applies to Maturity Level 2 PAs when pursuing Level 3

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Generic Practices Requiring Measurements

- GP 2.2 – Establish and maintain the plan for performing the process
  - Requires defining the process and preparing a plan to perform the process
  - Would normally be covered under the Project Planning process for project-related processes
  - Measurements are needed to quantify the plan for the process, e.g., duration and effort

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Generic Practices Requiring Measurements

- GP 2.8 - Monitor and control the process against the plan for performing the process and take appropriate corrective action
  - Provide immediate management with appropriate visibility into the performance and status of the process against the plan
  - Measurements are needed to track the status of the process versus the plan, e.g., schedule and effort

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Generic Practices Requiring Measurements

- GP 2.10 - Review the activities, status, and results with higher level management and resolve issues
  - Normally requires periodic and event driven reviews with 2nd-level management or above to provide appropriate visibility into the process
  - Measurements are needed to quantify status and results of using the process

Generic Practices Requiring Measurements

- GP 3.2 – Collect work products, measures, measurement results, and improvement information derived from planning and performing the process to support the future use and improvement of the organization's processes and process assets
  - Requires an organizational process asset library and organizational measurement repository for process measurements

Specific Practices Requiring Measurements

- Project Planning
  - SP 1.2 - Establish estimates of work product and task attributes
  - SP 1.4 - Determine estimates of effort and cost
  - SP 2.1 - Establish the budget and schedule
  - SP 2.4 - Plan for project resources
  - Above SPs can support other PAs' GP 2.2s
- Project Monitoring and Control
  - SP 1.1 - Monitor Project Planning Parameters
    - Can support other PAs' GP 2.8
  - SP 1.6 - Conduct Progress Reviews
  - SP 1.7 - Conduct Milestone Reviews

Specific Practices Requiring Measurements

- Requirements Management (REQM)
  - SP 1.3 – Manage changes to the requirements as they evolve during the project
- Configuration Management (CM)
  - SP 2.1 – Track change requests for the configuration items
- Process and Product Quality Assurance (PPQA)
  - SP 2.2 – Establish records
- Integrated Project Management (IPM)
  - SP 1.2 – Use organizational process assets for planning project activities
  - SP 1.5 - Contribute to the organizational process assets
    - Supports other PAs' GP 3.2s

Specific Practices Requiring Measurements

- Organizational Process Focus (OPF)
  - SP 2.4 – Incorporate process-related experiences into the organizational process assets
    - Supported by all PAs' GP 3.2s
- Organizational Training – (OT)
  - SP 2.3 – Assess training effectiveness
- Verification
  - SP 2.3 – Analyze peer review data
  - SP 3.2 – Analyze verification results and identify corrective action
- Validation
  - SP 2.2 – Analyze validation results

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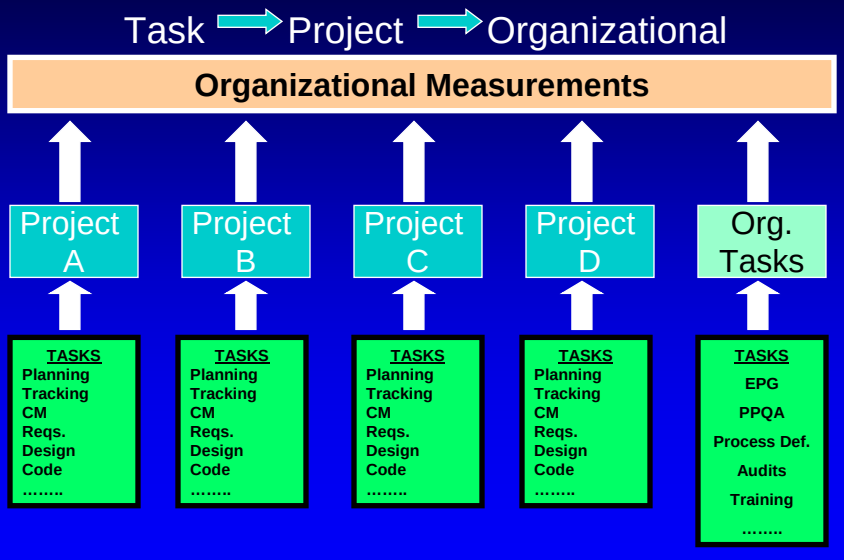
Levels of Data Collection and Reporting



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Recommendations
Task Level Effort and Schedule Data

- Place an emphasis on managing task-level effort and schedule
  - Planned vs. actual vs. % work complete
  - Supports GPs 2.2, 2.8, 2.10, 3.2
  - Supports institutionalization by budgeting time to perform each process and assessing how much time is actually being spent
  - Requires that people record their time to the task level (established by a project's WBS)
  - Requires actual effort data be combined with planned effort data for analysis
  - Supports process improvement through effort distribution analysis

Recommendations
Standard WBS

- Establish a standard WBS (but allow for some flexibility)
  - WBS establishes required level of formal tracking for effort (planned and actual) and schedule
  - Can usually be kept to 2 or 3 levels of hierarchy
  - Provides for consistent aggregation across projects for organizational analysis of effort distribution
  - Ensures all processes are measured that relate to CMMI Process Areas; thereby, addressing many of the Generic Practices
  - Consider documenting the Standard WBS as part of the Measurement Plan

Sample Project WBS

WBS#	Interpretation
1	General Tasks
1.1	Project Planning and Tracking
1.2	Supplier Management
1.3	Configuration Management
1.4	Process and Product Quality Assurance
1.4	Training/Startup/Indoctrination Support
1.6	Formal Customer Events
n*	Engineering Tasks
n.1	Software Requirements Definition
n.2	Design
n.3	Code
n.4	Unit Test
n.5	Integration and Test
n.6	Acceptance Test
n.7	Installation
n.8	Maintenance

*n = 2 = Function/Component A
*n = 3 = Function/Component B
etc.

Recommendations
% Work Complete or Earned Value Tracking

- An objective measurement of work progress is needed. One simple approach is:
  - Ensure every task on a schedule is given a budget
  - Subdivide every task until lowest level tasks do not exceed 2 – 3 weeks
  - Regularly estimate % complete for lowest level tasks. Consider restricting entries to:
    - 0%-50%-100%
    - 0%-25%-50%-75%-100%
  - Rollup of budgeted (weighted) sub-tasks yields % complete for major tasks and overall project
  - Apply this % complete to analysis of cost, effort, schedule status
- Industry best practice: Earned Value Management

Project Estimating vs. Planning

- Estimation involves:
  - First, estimating what is to be produced in units of size, e.g., function points, lines of code, etc.
    - Break project down into manageable "chunks"
    - Estimate the size of each chunk based upon historical data
  - Applying a productivity rate (units/hour) to obtain labor hours
    - Estimate the productivity rate based upon historical data
  - Estimating all other support tasks (based upon historical data)
  - Identifying non-labor costs, e.g., equipment, licenses, etc.
  - Calculating total cost by applying labor rates and unit costs
- Planning involves establishing task schedules, resource usage and spending plans allocated over the life of the project

Organizational Activities

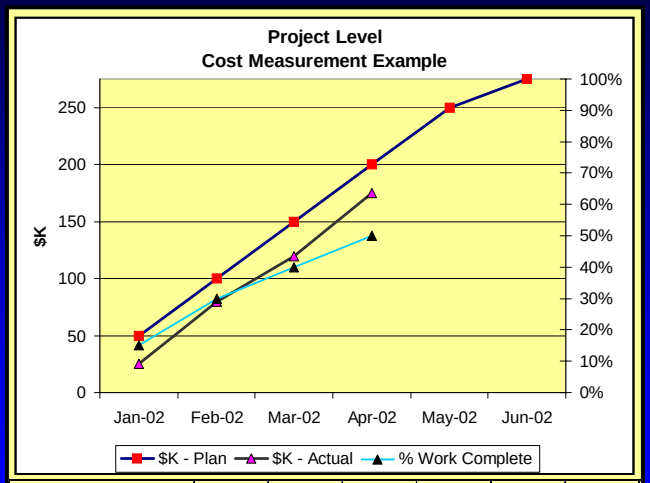
- Plan and track organizational activities according to how they are funded and managed. For example, an Engineering Process Group (EPG) may be responsible for:
  - Implementing software process improvements (PAs: OPF)
  - Generating and maintaining process documents (PA: OPD)
  - Coordinating organizational training (PA: OT)
  - Establishing and managing the measurement program (PA: MA)
- Establish and track budgets, schedules, resource and effort plans, and cost spending plans just as a project would
- Track cost at the level it is funded by the organization, e.g., for all EPG activities, but not to the task level
- Track effort to the individual major task level
- Same as above for PPQA

Recommended CMMI Measures

Measures	CMMI SPs/GPs	Business Need Supported	Justification	Level of Tracking
1) Cost planned vs. actual for: • Project Costs • Org. activities*	PP-SPs 1.4, 2.1 IPM-SP 1.2 PMC-SPs 1.1, 1.6, 1.7 OPF-GPs 2.2, 2.8, 2.10	Meeting cost commitments	To manage cost commitments; to identify & address cost issues as early as possible	Project
2) Effort **3) Schedule** planned vs. actual for: • Engineering tasks • Project mgmt. tasks • Supplier Mgmt. • Configuration Mgmt. • PPQA • EPG tasks • Training	PP-SP 1.4, 2.1 IPM-SP 1.2 PMC-SP 1.1, 1.6, 17 For all PAs: GPs 2.2, 2.8, 2.10, 3.2	Meeting cost and schedule commitments	To identify and address staffing and schedule issues; to support current & future planning	Project, Task

* - assuming organizational activities, like OPD, OPF, OT, MA have one cost budget combined. Representing collectively as an OPF project.

Sample Chart



Cost ($K)	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02
$K - Plan	50	100	150	200	250	275
$K - Actual	25	80	120	175		
% Work Complete	15%	30%	40%	50%		

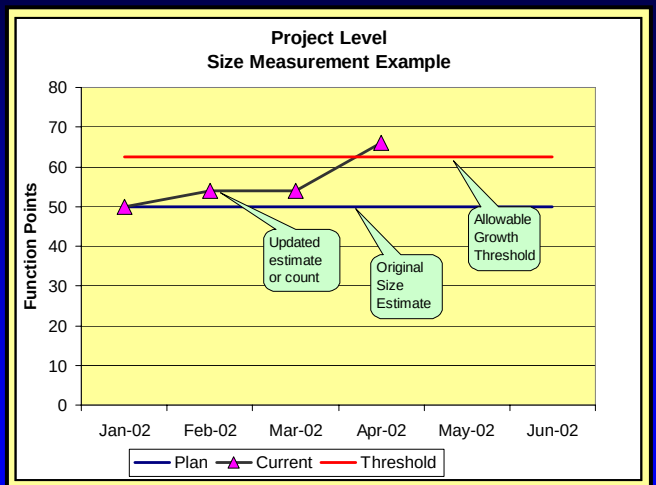
Can use similar chart for Effort

Recommended CMMI Measures

Measures	CMMI SPs/GPs	Business Need Supported	Justification	Level of Tracking
4) Size (e.g., Function Points) – estimated vs. current	PP-SPs 1.2 IPM-SP 1.2 PMC-SPs 1.1, 1.6, 1.7 REQM-SP 1.3	Meeting cost, schedule, and functionality commitments	To identify and address scope issues, e.g., "reqs. creep"; to support current replanning and future planning; to support productivity	Project
5) Critical Resources - planned vs. actual	PP-SP 2.4 PMC-SP 1.1	Meeting technical commitments	To manage critical hardware requirements	Project

* - assuming organizational activities, like OPD, OPF, OT, MA have one cost budget combined. Representing collectively as an OPF project.

Sample Chart



Size (Function Points)	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02
Plan	50	50	50	50	50	50
Current	50	54	54	66		
Threshold	62.5	62.5	62.5	62.5	62.5	62.5

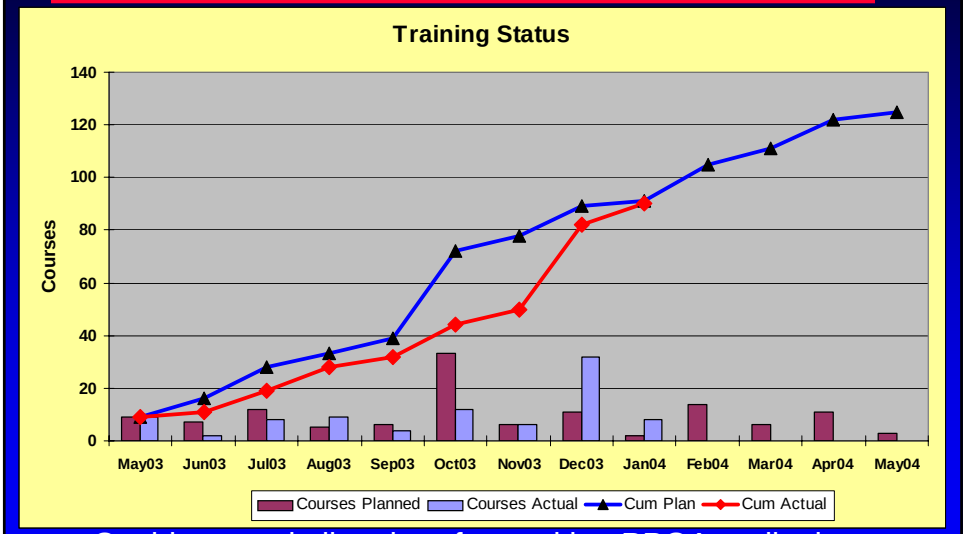
Recommended CMMI Measures

Measures	CMMI SPs/GPs	Business Need Supported	Justification	Level of Tracking
6) Peer Review, Test and Defect Data • Performance data • Defect profile	VER-SPs 2.3, 3.2 & GPs 2.8, 2.10, 3.2 VAL-SP 2.2 & GPs 2.8, 2.10, 3.2	Meeting and improving product quality needs	To manage, assess and improve product quality	Org., Project, Task
7) Change Requests & Problem Reports • Disposition status • Impact estimates	REQM-SP 1.3, GPs 2.8, 2.10, 3.2 CM-SP 2.1, GPs 2.8, 2.10, 3.2	Managing quality	To track the disposition of SW bugs and change requests	Org., Project
8) Project Completion Data • Final Size • Productivity • Effort Distribution • Defect Insertion and Removal	IPM-SP 1.5 PP-GP 3.2 VER & VAL-GP 3.2 OPF-SP 2.4	Supporting process improvement	To support future planning; to analyze process capability	Org., Project

Recommended CMMI Measures

Measures	CMMI SPs/GPs	Business Need Supported	Justification	Level of Tracking
9) Training – planned vs. actual	OT-GPs 2.2 2.8, 2.10	Managing training	To plan and track training to ensure business needs are met	Org., Project
10) Training Effectiveness • Scores per evaluation category	OT-SP 2.3	Managing training effectiveness	To identify and improve aspects of training courses that need improvement	Course
11) PPQA Audit results • % of non-compliance findings per audit trend • Corrective action status	PPQA-SP 2.2	Managing process compliance	To ensure processes are compliant to documented procedures and standards	Org., Project, Procedure and products

Sample Training Status Chart



Could use a similar chart for tracking PPQA audit plan

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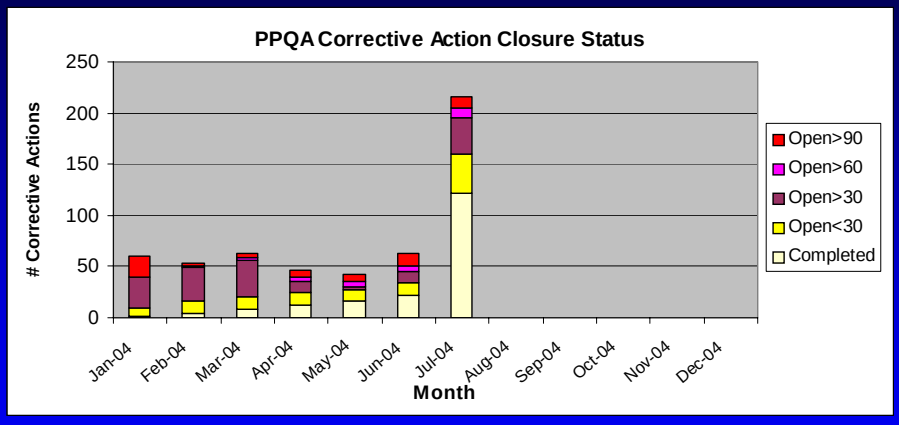
Sample PPQA Chart



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Peer Review and Test Measures

- Program, function, and work product identifiers
- Type and phase of review or test, e.g., design inspection or unit test
- Who attended and how much time was spent preparing (reviews)
- How long the review meeting lasted (reviews)
- Size of the work product, e.g., pages of design
- Total defects detected (by severity)
- Time spent fixing defects (rework)
- Analysis could include:
  - Defects found per hour of detection
  - % of time in preparation
  - Meeting rate (ex: pages per meeting hour)
  - Etc.

Peer Review and Test Defect Data

- For each defect found:
  - Defect type, e.g., missing, wrong, or extra
  - Defect origin, i.e., what phase when inserted
  - Defect severity, i.e., major or minor
  - Defect category (optional), e.g., logic, data, etc.
  - Defect location, e.g., module or program element name
  - Work product ID, e.g., change ID#
  - Type of review or test when found, e.g., Code Inspection, Unit Test, etc.
  - Date closed
  - Time to Fix – the amount of time to fix and revalidate

Example of Defect Insertion & Removal Profile

Rate = Ave. Defects/KSLOC	*Peer Reviews*			*Testing*				
Range	**Reqs**	**Design**	**Code**	**Unit Test**	**Int Test**	**Sys Test**	**Field**	**Total**
Insertion Rate	2.5	7.2	22.7	0.9	0.3	0.1	0.0	
Detection Rate	1.0	5.0	17.0	4.0	2.5	2.0	2.0	33.6
Leakage Rate	1.5	3.6	9.3	6.1	3.9	2.0	0.0	
Removal Effectiveness	40%	58%	65%	40%	39%	50%	100%	
*Average | Best in Class**	*40% | 50%*	*70% | 85%*	*65% | 85%*	*35% | 55%*	*35% | 45%*	*40% | 55%*		
			Peer Review Effectiveness->	71%	*Total Effectiveness->*		94%	
			Best in Class->	85+%	*Best in Class->*		99+%	

* from Capers Jones, *Software Assessments, Benchmarks and Best Practices*, Addison Wesley, 2000

Analysis of insertion rates and defect-removal effectiveness against industry benchmark data provides valuable information about an organization's software process capability and reveals areas that need improvement.

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Analysis for Continual Improvement

- At the organizational level, aggregate project data to determine overall process performance, especially for:
  - Effort distribution by task
  - Productivity
  - Defect Insertion and Removal Effectiveness
- Establish and maintain performance and productivity profiles for projects to use during project estimating and planning
- Continually address data integrity issues so the data can be trusted
- Establish a commitment to quality and process improvement
  - Report regularly to senior management
  - From analysis, create action plan for improvement
  - Ensure action plan is sponsored by management and carried out successfully
  - Measure to assess results of improvement actions

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