

The Capability Maturity Model

**PMI Westchester Chapter
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Software Process

“The software process is the set of tools, methods, and practices used to produce a software product.”

- Watts Humphrey,
Managing the Software Process

The quality of a software system is largely governed by the quality of the process used to develop and maintain it.



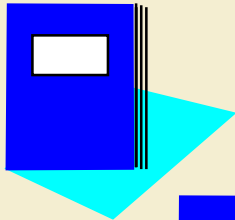
Model Based Process Improvement

- A model identifies key process areas and associated practices that are typical of companies at different levels of process maturity
- Organizations implement process improvements and periodically assess progress by comparison to the model
- Model Based Improvement Benefits
 - Establishes a common language
 - Forges a shared vision
 - Builds on a set of processes and practices developed with input from a broad selection of the software community
 - Provides a framework for performing reliable and consistent appraisals
 - Supports industry-wide comparisons

Software CMM

- **CMM provides a conceptual framework based on state-of-the-art software engineering practices that help software organizations to**
 - **assess the maturity of their processes**
 - **establish goals for process improvement**
 - **set priorities for immediate action**
 - **envision a culture of software engineering excellence**
- **Maturity levels range from 1 to 5**
 - **Lower maturity organizations are less likely to repeat individual successes**
 - **Higher maturity organizations are more likely to be able to systematically repeat successes and take advantage of opportunities for improvement**

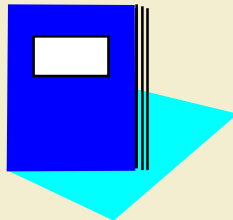
CMM - History



“A Method for Assessing the Software Engineering Capability of Contractors”

- Watts Humphrey et. al., CMU/SEI-87-TR-23, 1987

(85 graded questions, 101 total)



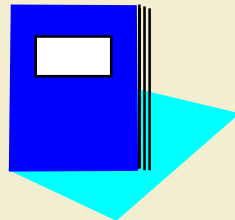
“Characterizing the Software Process: A Maturity Framework”

- Watts Humphrey, IEEE Software, 1988

Software Level	Software Process	Key Practices
1. Initial	<ul style="list-style-type: none"> Plan to change management Checklist management Project planning 	Quality & Productivity
2. Repeatable	<ul style="list-style-type: none"> Plan to change management Checklist management Project planning 	Quality & Productivity
3. Defined	<ul style="list-style-type: none"> Plan to change management Checklist management Project planning 	Quality & Productivity
4. Managed	<ul style="list-style-type: none"> Plan to change management Checklist management Project planning 	Quality & Productivity
5. Optimizing	<ul style="list-style-type: none"> Plan to change management Checklist management Project planning 	Quality & Productivity

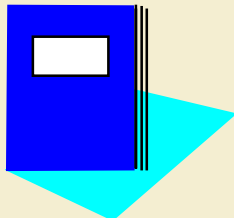
Assessment and Evaluation Training

- SEI 1988



“Managing the Software Process”

- Watts Humphrey, 1989

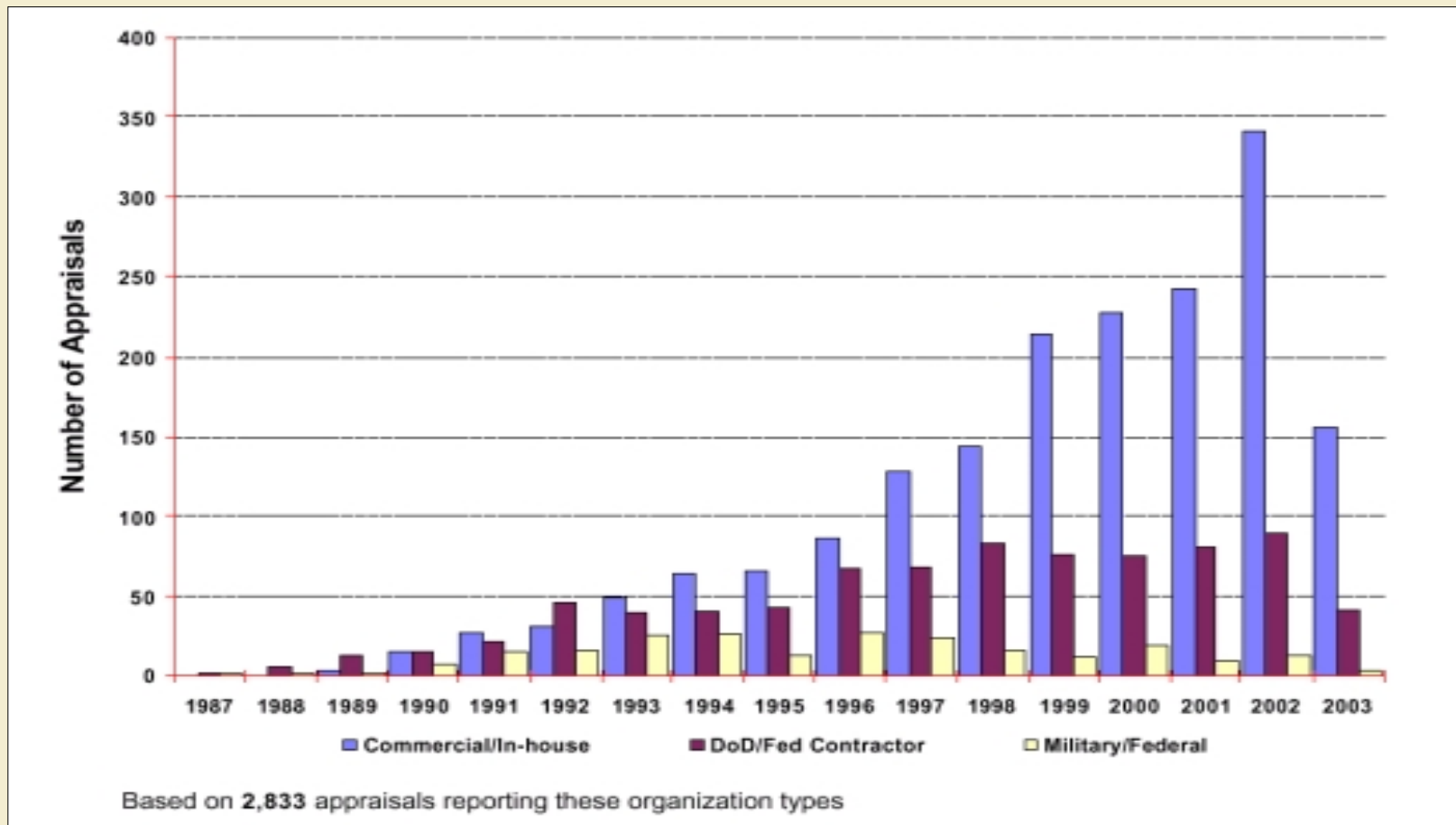


“Key Practices of the Capability Maturity Model for Software”

- Paulk et. al., CMU/SEI-93-TR-25, 1993

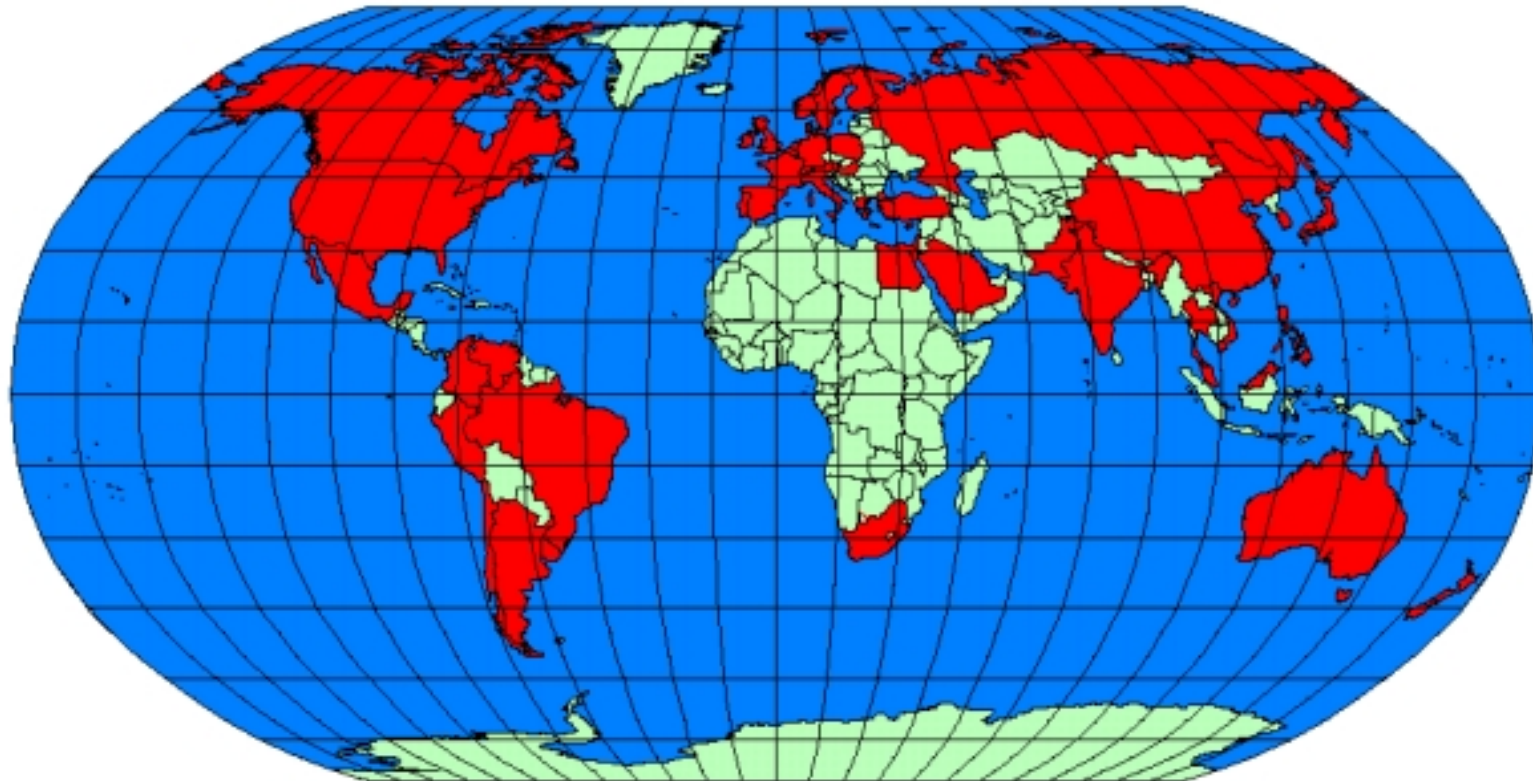
(246 pages of process model)

Number of CMM Based Appraisals



**Process Maturity Profile Software CMM CBA-IPI and SPA
Appraisal Results 2003 Mid-Year Update, Sept 2003**

Countries using CMM Based Appraisals



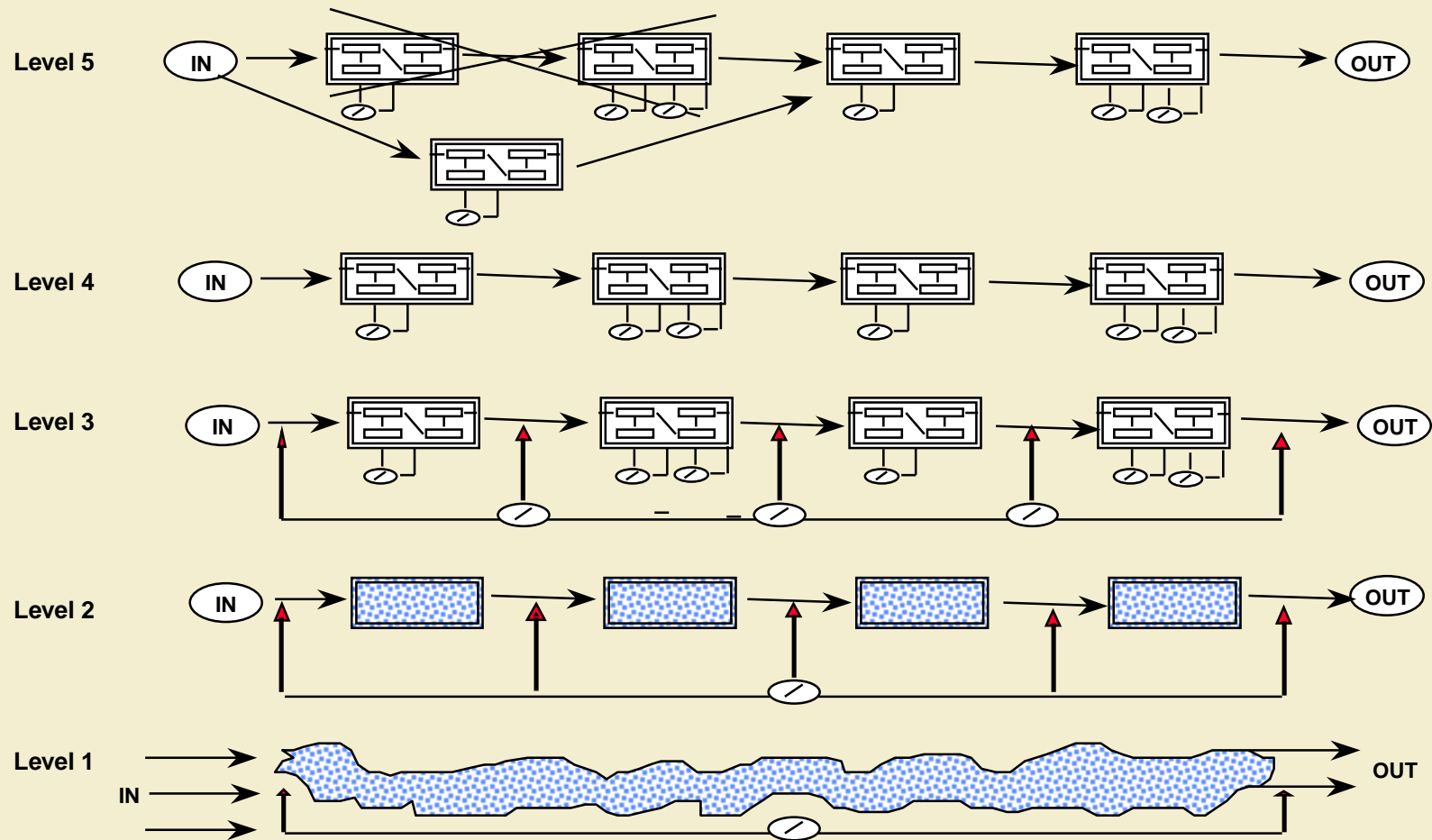
Argentina	Australia	Austria	Barbados	Belgium	Brazil	Canada	Chile
China	Colombia	Cyprus	Denmark	Egypt	Finland	France	Germany
Greece	Hong Kong	Hungary	India	Ireland	Israel	Italy	Japan
Korea, Republic of	Malaysia	Mexico	Netherlands	New Zealand	Norway	Pakistan	Peru
Philippines	Poland	Portugal	Puerto Rico	Russia	Saudi Arabia	Singapore	South Africa
Spain	Sweden	Switzerland	Taiwan	Thailand	Turkey	United Kingdom	United States
Uruguay	Venezuela	Viet nam					

Process Maturity Profile Software CMM CBA-IPI and SPA Appraisal Results 2003 Mid-Year Update, Sept 2003

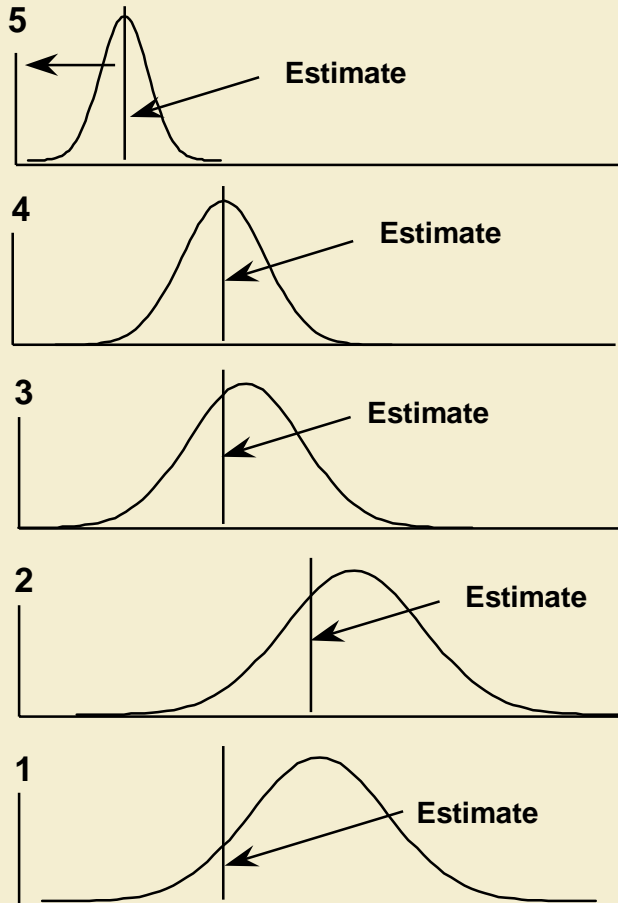
CMM Levels

Maternity Levels	Key Process Areas	Results
5 Optimizing <i>continuous improvement a reality</i>	<ul style="list-style-type: none"> •Process change management •Technology innovation •Defect prevention 	Quality & Productivity
4 Managed <i>statistical process control in place</i>	<ul style="list-style-type: none"> •Quality management •Process measurement and analysis 	
3 Defined <i>all projects use a documented variant of the standard organizational process</i>	<ul style="list-style-type: none"> •Peer reviews •Inter-group coordination •Software product engineering •Integrated software management •Training program •Organization process definition •Organization process focus 	
2 Repeatable <i>management process adequate to repeat earlier successes on similar projects</i>	<ul style="list-style-type: none"> •Software configuration management •Software quality assurance •Software subcontract management •Software project tracking and oversight •Software project planning •Software requirements management 	
1 Initial <i>chaotic - success depends on individuals</i>	<ul style="list-style-type: none"> •None 	Risk

Measurement & Management in CMM



CMM Levels and Process Performance



SCHEDULE/COST/QUALITY

- Level 1 organizations consistently underestimate and have a wide variation in process performance from project to project
- An effective level 2 process will improve the accuracy of estimates, but will have a minimal impact on variability and average performance
- An effective level 3 process will improve average performance and predictability
- With an effective process, level 4 will be highly predictable and level 5 will have a dramatic performance improvement
- However, an ineffective process will only add overhead no matter what the level!

Initial Organizations (1)

- **“benefits of good software engineering practices are undermined by ineffective planning and reaction-driven commitment systems”**
- **“during a crises, projects typically abandon planned procedures and revert to coding and testing”**
- **“capable and forceful software managers can withstand the pressure to take shortcuts ... but when they leave the project, their stabilizing influence leaves with them”**
- **“performance depends on the capabilities of individuals and varies with their innate skills, knowledge, and motivations”**
- **“even a strong engineering process cannot overcome the instability created by the absence of sound management practices”**

Repeatable Organizations (2)

- “project’s process is under the effective control of a project management system, following realistic plans based on the performance of previous projects”
- “realistic project commitments are based on the results observed on previous projects and on the requirements of the current project”
- “effective management processes for software projects... allow organizations to repeat successful practices developed on earlier projects, although the specific processes implemented by the projects may differ”

Defined Organizations (3)

- “standard process for developing and maintaining software across the organization is documented, including both software engineering and management processes, and these processes are integrated into a coherent whole”
- “a group ... is responsible for the organization’s software process activities, e.g. a Software Engineering Process Group, or SEPG”
- “projects tailor the organization’s standard software process to develop their own defined software process”
- “management has good insight into technical progress on all projects”
- “within established product lines, cost, schedule, and functionality are under control, and software quality is tracked”

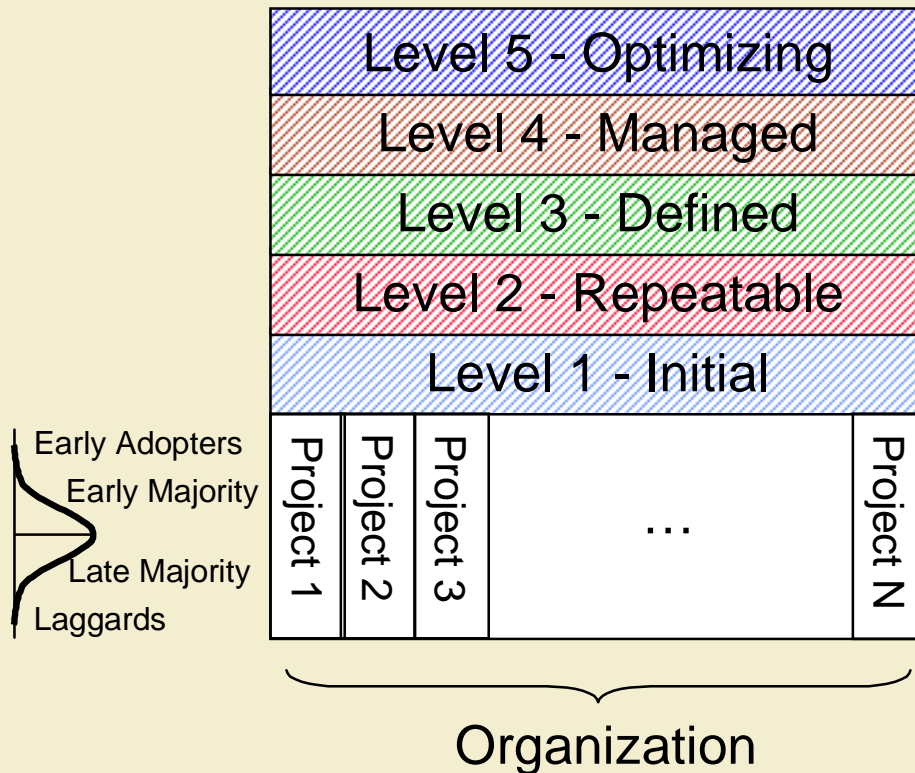
Managed Organizations (4)

- “productivity and quality are measured for important software process activities across all projects as part of an organizational measurement system”
- “projects achieve control over their products and processes by narrowing the variation in the process performance to fall within acceptable quantitative boundaries”
- “this level of process capability allows an organization to predict trends in process and product quality ... when ... limits are exceeded, action is taken to correct the situation”
- “software products are of predictable high quality”

Optimizing Organizations (5)

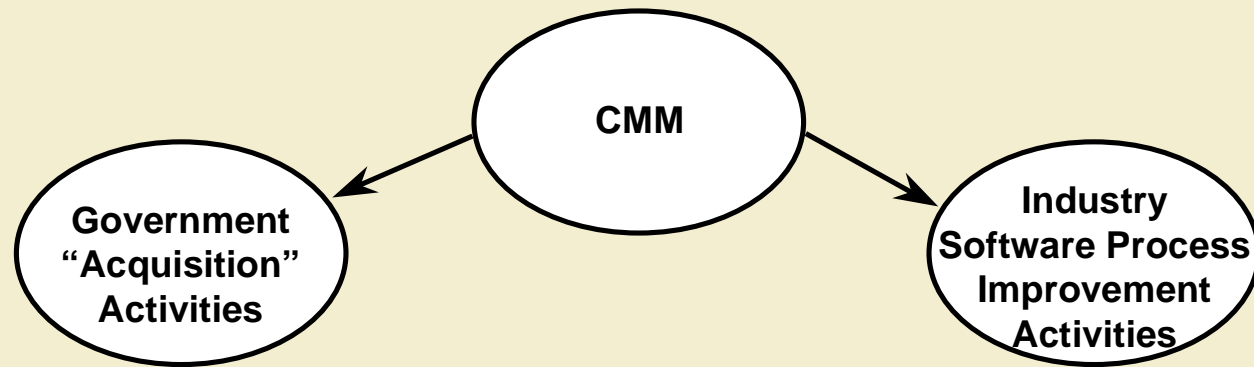
- “organization is focused on continuous process improvement”
- “innovations that exploit the best software engineering practices are identified and transferred throughout the organization”
- “software project teams ... analyze defects to determine their causes. Software processes are evaluated to prevent known types of defects from recurring, and lessons learned are disseminated to other projects”

Staged Improvement Model



- Processes at the lower levels provide the foundation for processes at the higher levels
- Success at the lower levels prepares the organization to accept the changes required at the higher levels
- Most of the organization's projects move forward more or less in parallel one level at a time
- The main drawback is organizational inertia – due to change resistance, it can literally take years to move a level

APPRAISALS



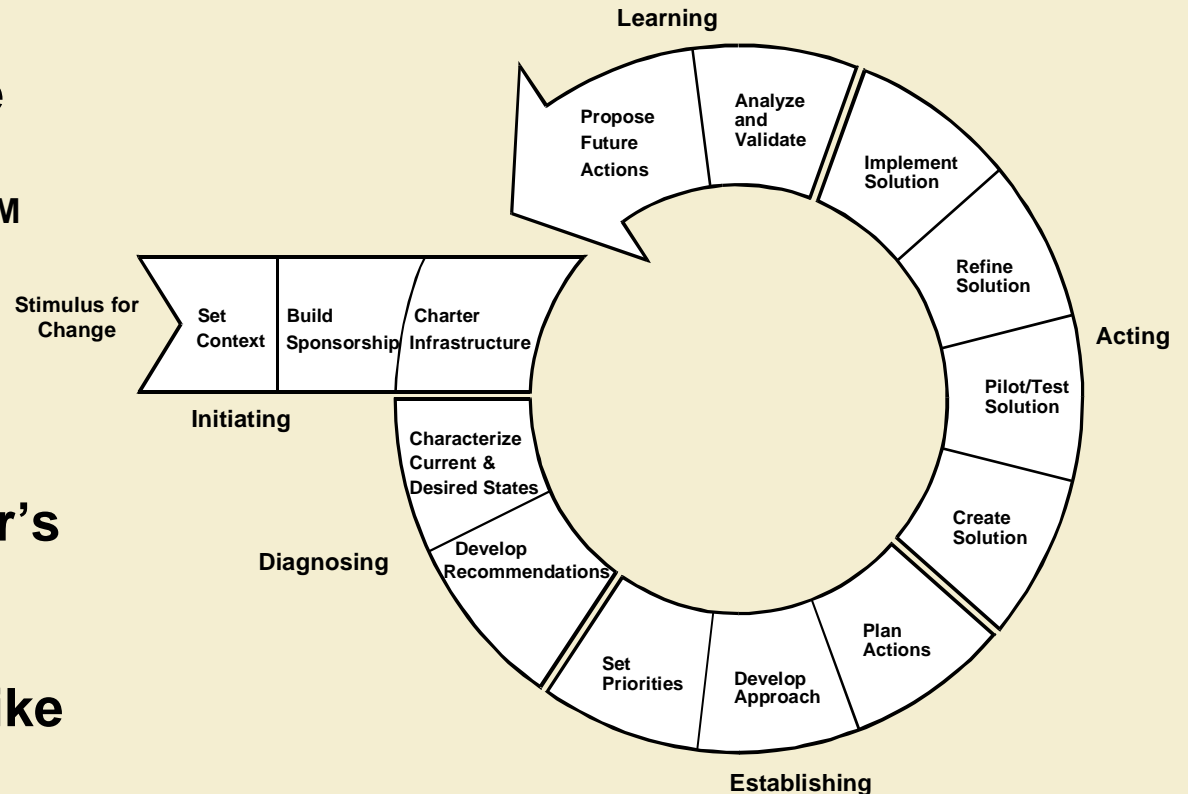
SCE: "Risk" associated with a Supplier's Process Capability

CBA-IPI: Internal Process Improvement Within Corporations

- **Provide an accurate picture relative to the CMM**
 - Collect process data to understand the current process
 - Identify process strengths and improvement opportunities
 - Determine the degree to which CMM KPAs are satisfied
- **Facilitate continued commitment to SPI**
 - Motivate — Obtain the "buy-in"
 - Build ownership of results
 - Provide a framework and catalyst for action
 - Sustain sponsorship and establish commitment

Process Improvement Method

- IDEALSM model is frequently used in conjunction CMM style process improvement
- A new cycle of IDEALSM based improvement is initiated with each assessment
- Drawback: IDEALSM cycles can be 1 - 2 year's long!
- Consider alternate improvement models like Six Sigma's DMAIC



CMM Pitfalls

- **Many organizations take years to move from level to level**
 - CMM does not identify a specific process and does not provide guidance on change management and improvement methods
 - A Naïve application of staged model tries to move the entire organization at once, from early adopters to laggards, and can encounter lots of resistance
 - For organizations that began their CMM-based SPI effort in 1992 or later, the median time to move from:
 - ♦ Maturity level 1 to 2 is 22 months
 - ♦ Maturity level 2 to 3 is 21 months
 - ♦ Maturity level 3 to 4 is 25 months
 - ♦ Maturity level 4 to 5 is 13 months
- **Watts Humphrey originally thought most organizations would move from level 1 to 5 in one or two years!**

CMM Pitfalls

- CMM is not a process
 - It tells you what to do not how to do it
 - Can result in ineffective processes with excessive documentation
- Many organizations don't understand how to define an efficient process and they implement processes that are CMM level 2 or level 3 compliant, but that actually add overhead without improving productivity, predictability, and product quality
- Some organizations purchase turn-key solutions by purchasing command media or tools that guarantee CMM compliance but are not accepted by the developer community and end up as “shelf-ware”

CMM Pitfalls

- **Many organizations get no improvement at all because the developers don't actually use the new processes!**
 - Processes that have minimal impact on the developers will have minimal business value as well
 - Process documentation is no substitute for training, leadership, and motivation
- **Many more organizations fail to progress at all or drop back a level within six months of an assessment**
 - Lack of a perceived problem
 - Frequently poor alignment between project management & SEPG
 - Failure to get and maintain adequate sponsorship
 - Emphasizing level goals at the expense of business objectives

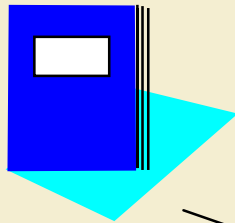
CMM Pitfalls

- **Strict adherence to the staged model defers implementing a measurement framework to level 4**
 - failure to baseline initial capability makes it impossible to compute ROI and difficult to retain sponsorship
 - failure to measure a process implies failure to manage its performance - even when initial process is effective, performance decays quickly without pro-active management
- **Because level 3 was the minimum level required for American military contracts, many organizations think that level 3 is “good enough”**
 - Level 3 requires most of the investment, but most of the benefits accrue at levels 4 and 5!
 - The first level 5 company, IBM Federal Systems, produced safety critical software for the Space Shuttle at very high cost per line - its process was designed for safety at the price of efficiency!

CMM & Outsourcing

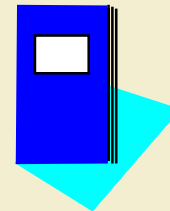
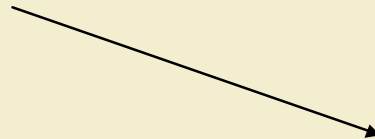
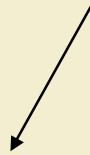
- Many outsourcing organizations use CMM level as a sales tool
- Don't be naïve about selecting a vendor based on CMM level
 - Who did the assessment?
 - ♦ Internal assessments can be politically motivated
 - ♦ There are ethics issues with some external assessors
 - When was it done?
 - ♦ There is no requirement to periodically re-assess as with ISO
 - ♦ In today's dynamic environment, any assessment more than a few years old is probably irrelevant
 - Does the vendor follow its process?
 - ♦ Surprisingly many don't!
 - Does the vendor's process perform well?
 - ♦ Remember a relatively ineffective process can be technically compliant

Continuing Evolution



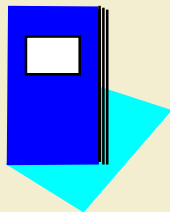
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- Paulk et. al., CMU/SEI-93-TR-25, 1993



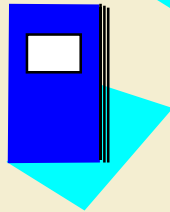
“A Discipline for Software Engineering”

- Watts Humphrey 1995



“CMM Version 2, Daft C”

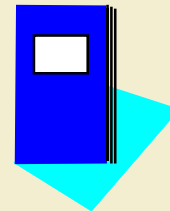
- SEI, 1997



“CMMI Version 1.1”

- SEI-99-TR-002, 1999

(729 pages of process model!)



“Introduction to the Team Software ProcessSM”

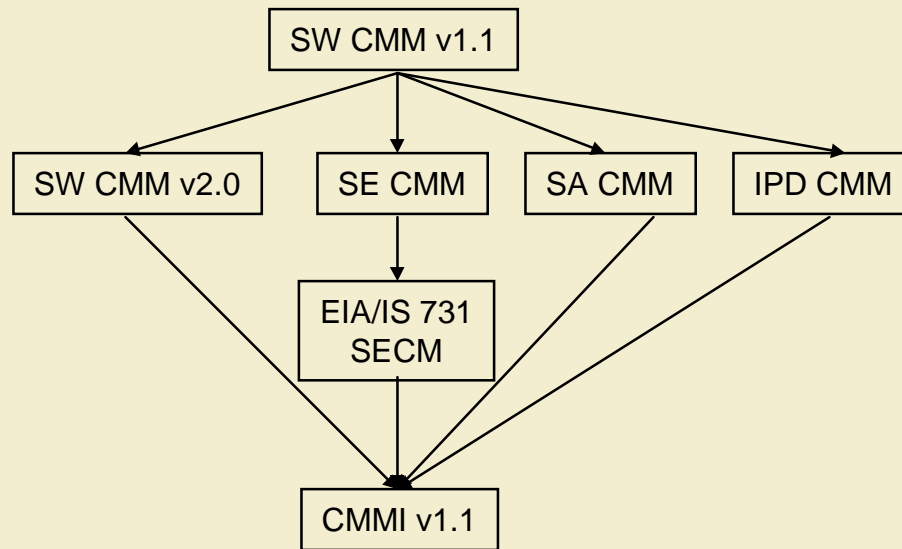
- Watts Humphrey, 2000

Capability Level	Key Process Areas	Goal & Priority
1. Managed	Requirements Management	Establish and maintain requirements
2. Planned and Controlled	Software Requirements Management	Establish and maintain requirements
3. Defined	Software Requirements Management	Establish and maintain requirements
4. Quantitatively Managed	Software Requirements Management	Establish and maintain requirements
5. Optimizing	Software Requirements Management	Establish and maintain requirements

Standard CMMI® Appraisal Method for Process Improvement (SCAMPISM) Version 1.1.

- SEI-2001-HB-001, 2001

CMMI



Capability Maturity Model Integration

- **Integrated CMM's covering**
 - Software
 - Systems Engineering
 - Software Acquisition
 - Integrated Product Development
- **Emphasis on measurable improvements to achieve business objectives.**
- **Process areas have been added to place more emphasis on some important practices:**
 - Risk Management
 - Measurement and Analysis
 - Engineering Process Areas
 - Decision Analysis
- **Continuous representation offered as alternative to staged representation**

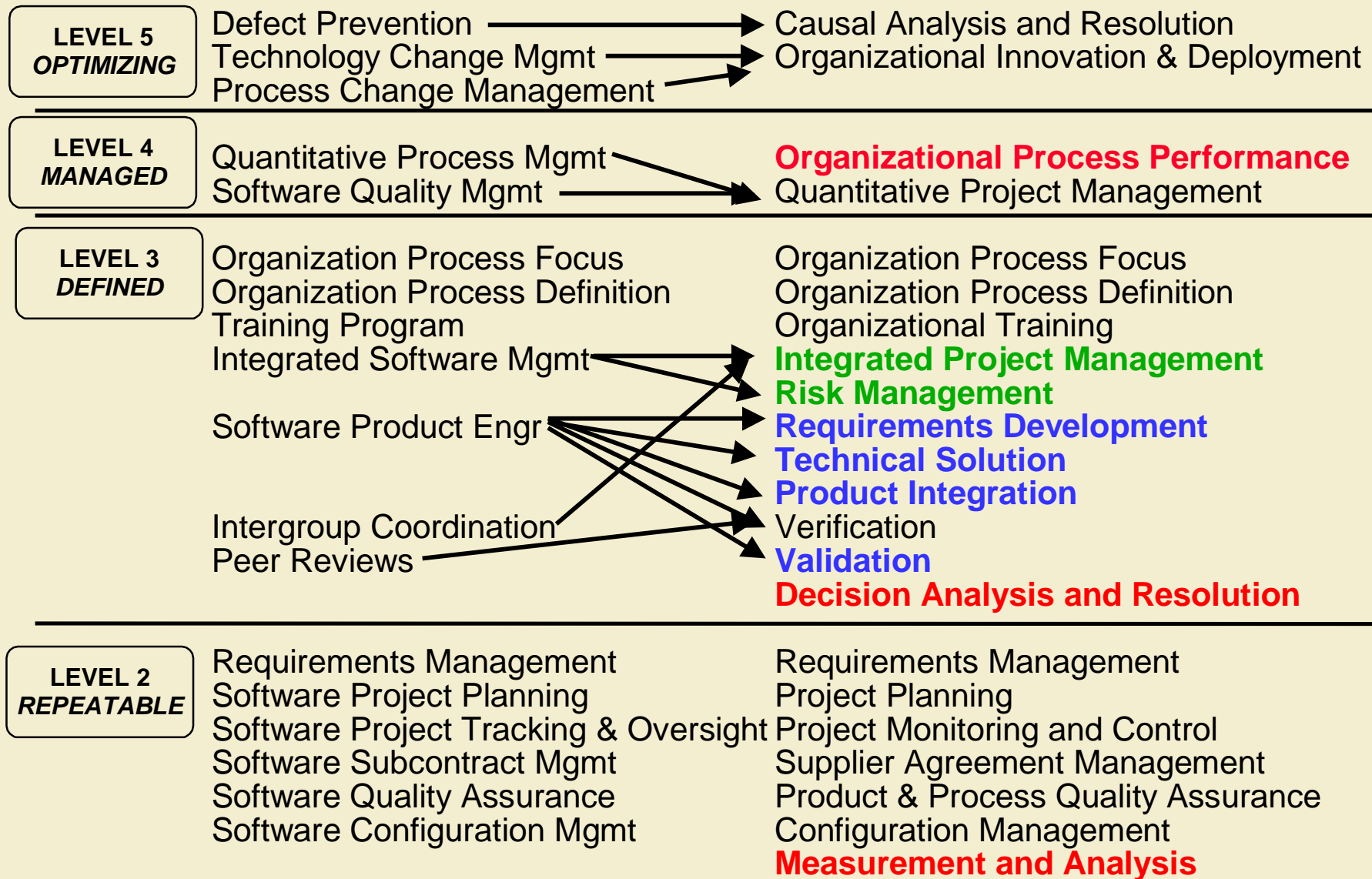
Process Areas by Maturity Level

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

Continuous Representation

Category	Process Area
Project Management	Project Planning Project Monitoring and Control Supplier Agreement Management Integrated Project Management (IPPD) Integrated Supplier Management (SS) Integrated Teaming (IPPD) Risk Management Quantitative Project Management
Support	Configuration Management Process and Product Quality Assurance Measurement and Analysis Causal Analysis and Resolution Decision Analysis and Resolution Organizational Environment for Integration (IPPD)
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

Comparing CMM & CMMI Process Areas



Assessments to Date

- **CBA IPIs and SPAs conducted since 1987 through June 2003 and reported to the SEI by July 2003**
 - 2,835 appraisals (2,351 CBA IPIs, 484 SPAs)
 - 2,150 organizations
 - 715 participating companies
 - 544 reappraised organizations
 - 11,823 projects
- **SCAMPI v1.1 appraisals conducted since April 2002 release through June 2003 and reported to the SEI by July 2003**
 - 100 appraisals
 - 93 organizations
 - 52 participating companies
 - 6 reappraised organizations
 - 357 projects

Personal Software Process

- **Watts Humphrey, the originator of the CMM, developed the Personal Software Process (PSP) in the early 1990's to address the shortcomings that had become evident in the CMM**
- **PSP is a CMM level 5 process covering all the practices needed by an individual software developer**
 - **Developers learn to use it during a rigorous three week training course that is commercially available**
 - **It is a measurement driven closed loop process that uses feedback to provide high performance levels**
 - **It is an efficient process that typically results in 30% - 50% productivity improvements, improved product quality by a factor of 10, and provides estimates that are good to $\pm 20\%$.**
 - **Most developers are motivated to use it because they measure the improvement in their own work during the course**

Team Software Process

- After initial testing of the PSP, Watts Humphrey developed the Team Software Process (TSP).
 - TSP adds project planning and project management processes to PSP allowing PSP to be used effectively on large projects
 - TSP is designed to create and sustain high performance work teams
- When used in conjunction with PSP, TSP provides an effective level 5 process for individual project
- Organizations that run a TSP pilot see an effective level 5 process in use
 - This completely changes their perspective on SPI
 - They set much higher standards for productivity, quality, and predictability
 - They understand that high quality and predictability can be achieved with no increase in overhead

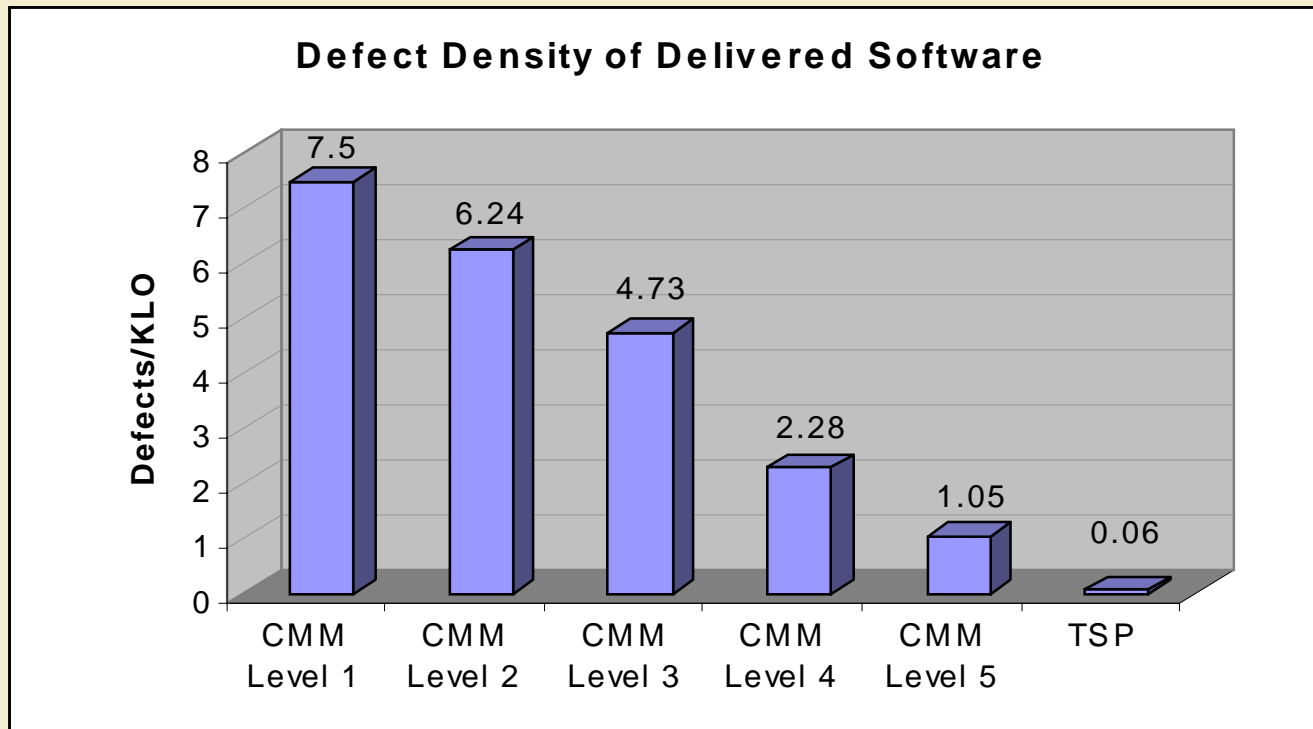
CMM Compliance for PSP & TSP

	% Fully Satisfied	% Partially Sat.	% Unsatisfied	% N/A	
Requirements Management	86%	14%	0%	0%	Level 2
Software Project Planning	84%	11%	0%	5%	Level 3
Software Project Tracking and Oversight	88%	12%	0%	0%	Level 4
Software Subcontract Management	35%	12%	53%	0%	Level 5
Software Quality Assurance	67%	25%	0%	8%	
Software Configuration Management	57%	43%	0%	0%	
Organization Process Focus	82%	18%	0%	0%	
Organization Process Definition	60%	0%	40%	0%	
Training Program	10%	30%	60%	0%	
Integrated Software Management	47%	27%	27%	0%	
Software Product Engineering	71%	29%	0%	0%	
Intergroup Coordination	45%	18%	36%	0%	
Peer Reviews	100%	0%	0%	0%	
Quantitative Process Management	91%	9%	0%	0%	
Software Quality Management	89%	0%	0%	11%	
Defect Prevention	58%	8%	33%	0%	
Technology Change Management	33%	50%	17%	0%	
Process Change Management	71%	29%	0%	0%	

Percent Averaging Technique	%Fully Satisfied	%Partially Sat.	% Unsatisfied	% N/A
Level 2	70%	19%	9%	2%
Level 3	59%	17%	23%	0%
Level 4	90%	5%	0%	6%
Level 5	54%	29%	17%	0%

- The table shows result of an analysis conducted by the SEI to examine the number of CMM KPA's satisfied by the standard PSP/TSP
- An organization that adopts PSP and TSP as a standard development practice immediately satisfies 70% of the level 2 KPA's, 59% of the level 3 KPA's, 90% of the level 4 KPA's, and 54% of the level 5 KPA's.

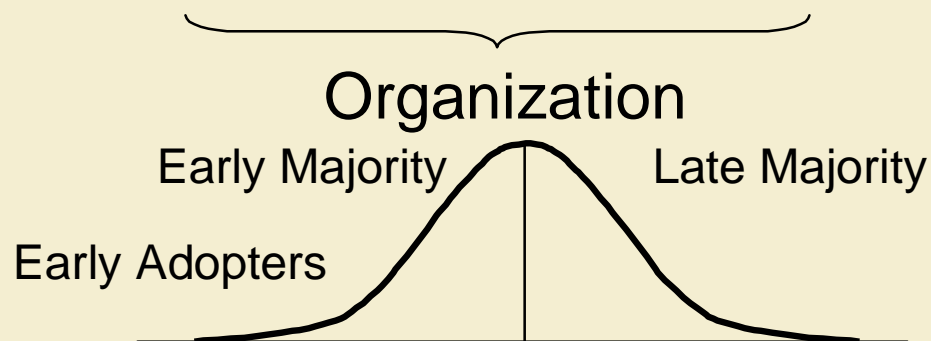
TSP and Product Quality



- *SEI data shows that TSP is capability of producing much higher product quality than other development processes, even than processes at typical level 4 and 5 organizations*
- The dramatically higher quality levels mean lower risk of product recall, higher customer satisfaction, and much lower maintenance & support costs

PSP Deployment Model

Level 5 - Optimizing				
Level 4 - Managed				
Level 3 - Defined				
Level 2 - Repeatable				
Level 1 - Initial				
Project 1	Project 2	Project 3	...	Project N



- PSP training moves a project team through the 5 CMM levels during a 12 day training course
 - Students make measurements of the impact of process changes on their own performance levels
 - Understand how to use the higher level processes effectively
- Pilot projects are staffed with early adopters.
- Successes are used to pull through the rest of the organization
- Number of teams doubles geometrically

Additional Information

- See our web site or for questions contact:

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