Concerns and Control of Software Engineering Practice

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Overview

- Processes
- The Software Crisis
- The Capability Maturity Model (CMM)
- Drawbacks of CMM
- Conclusions

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What Makes ***You*** Better?

- Why are *you* a better programmer than a first-year student?

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Some Answers...

- More training
  - Know how to use tools
  - Have seen some problems before
  - Know how things fit together
- Familiar with language
  - Object, semaphore, recursion, etc
- **Better process!**

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Examples of Better Processes

- Incremental coding
  - Code a little, test a little
  - Compare to writing *entire* program and testing
- Error prevention versus debugging
  - Cheaper and easier to prevent than to find bugs

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What Makes Organizations Better?

- Why are some organizations better than others?
  - Deliver software on time
  - Deliver with high quality and few defects
- Do some of the same things for a personal level scale up to organizations?
- Assume two groups are doing same project, why would one be better than another?

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Some Answers...

- Great people
- Smart management
- Better tools
- Good processes, standards and policies that all team members know and follow

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What is the Point of Processes?

- Basically, so we don't reinvent the wheel!
- Learn from mistakes
  - Never make the same mistake twice!
- Incorporate best practices
  - Something works better than another
- Routinization of standard tasks
  - Do it right once and then reuse it
- **Predictability**

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The Software Crisis

- Software is late, over budget, and low quality
- “Software Engineering” was coined in 1960s to apply engineering practices to software
- Third generation of hardware more powerful, led to larger systems
- Need new techniques and methods to control complexity

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Some Current Statistics

- Programmers tend to underestimate their tasks by 20 to 30% (van Genuchten 1991)
- The average small-project estimate is off by more than 100 % (Standish Group 1994)
- The average large project is a year late (Jones 1994)
- Less than 14% of projects larger than [~12,500,000 LOC in C] delivered on time (Jones)

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More Current Statistics

	%Late	%Cancelled
Small	14%	28%
Large	24%	48%
Really Large	21%	65%

From Ed Yourdon

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Goals of SE

- Improve the productivity of the development process
- Improve the comprehension of the developed software systems
- Improve the quality of the software product at all levels
  - Reliability
  - Efficiency (Speed, resource usage)
  - User-friendly (user acceptance)
  - Maintainability (comprehensive design and documentation)

- **General goal:** to produce quality software which is economic and useful and safe for people.

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Concerns of SE

- Products
  - Software products, test drivers (internal and external)
  - Paper documents (internal and external)
- Processes
  - How software is created (plan, tools, techniques)
  - How the quality is evaluated and ensured
- Tools
  - CASE tools, editors, project management tools, etc.
- People
  - Technical, social, and managerial skills
- Principles
  - Providing repeatability, guidelines and maturity in the software development process

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SEI-CMM

- Software Engineering Institute Capability Maturity Model (SEI-CMM, or CMM)
- CMM was developed by SEI at the request of the DoD in 1987
- Based on
  - Statistical quality control (Deming's TQM, Juran)
  - Quality management (Crosby)
  - Feedback from industry and government projects

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Why CMM?

- Government needs predictability
  - time, cost, quality
- Premises
  - The process of constructing software can be defined, managed, measured, and progressively improved
  - In a mature and adaptable process, people, methods, techniques, and technology are coupled to consistently produce quality software

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Why CMM?

- **Mature process**
- Disciplined
- Predictable
- Proven methods
- Managed
- Metrics for
  - Quality
  - Schedule
  - Cost
  - Functionality

- **Immature process**
- Ad hoc
- Unpredictable
- Improvised efforts
- Reactionary
- Few or no metrics

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CMM Organization

- Evolutionary path to increase software process maturity
  - Guide organizations in selecting improvement strategies
  - Small but continuous improvements
- Descriptive, not prescriptive
  - Describes goals but not how to achieve them
- Maturity characterized in five levels

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CMM Components

- Maturity levels
- Process capabilities
- Key process areas
- Goals and common features
- Key practices

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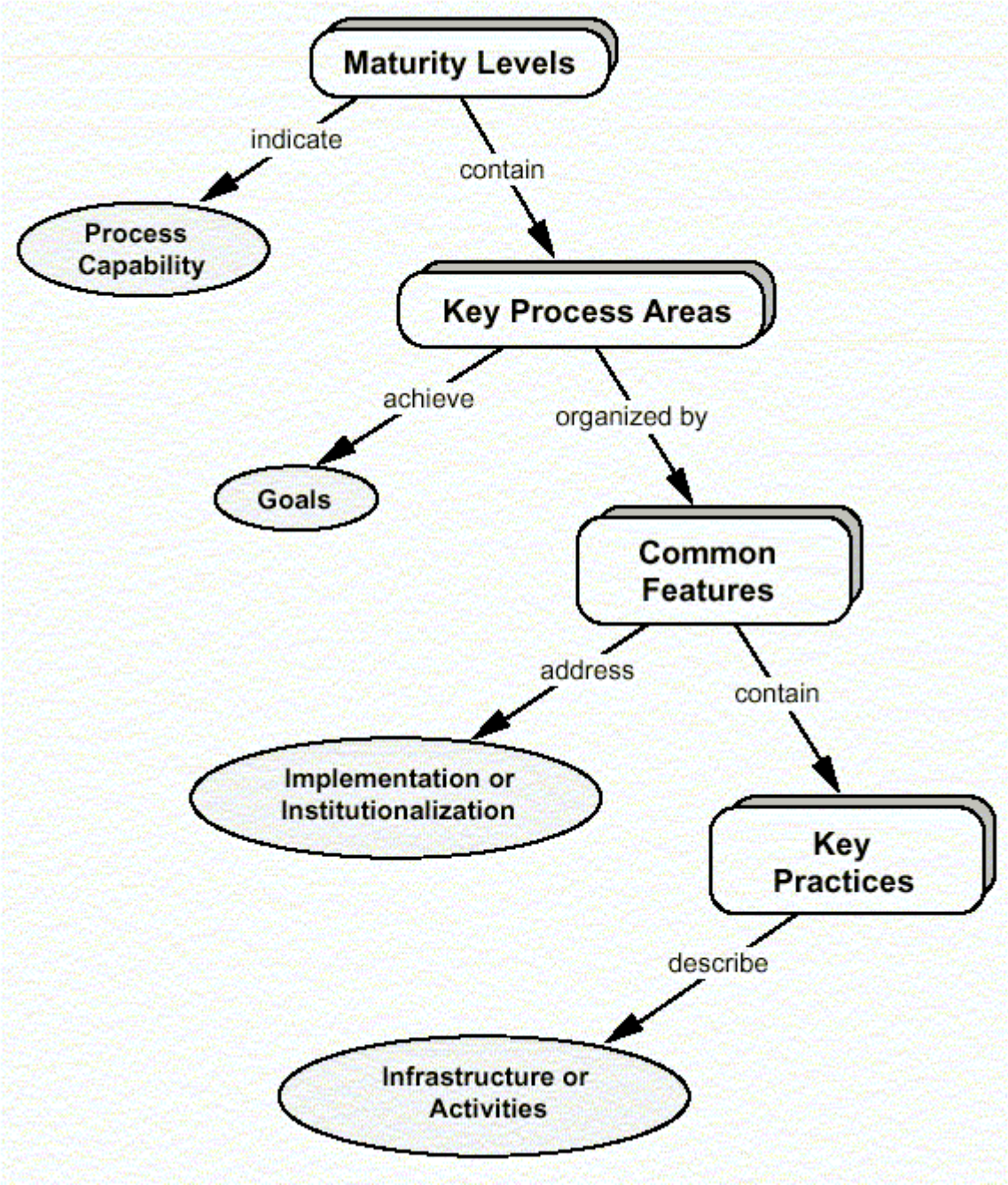
CMM

Components



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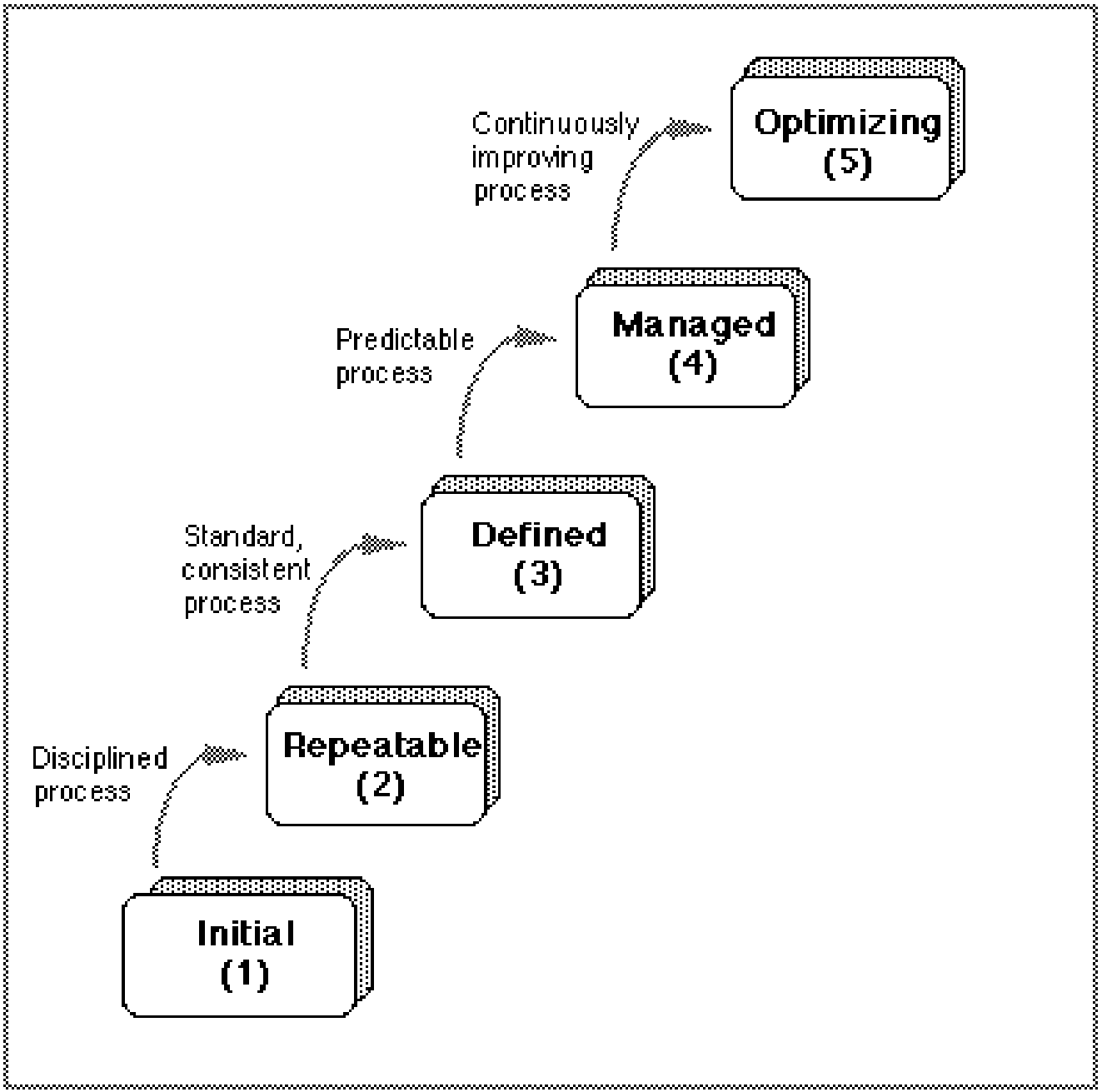
CMM Maturity Levels



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Level 1 - Initial

- Process is ad hoc, occasionally chaotic
- Few and informally defined processes
- No mechanism to ensure they are used consistently
- Ineffective planning
- Reaction-driven management
- Unpredictable
- *Success due to heroic efforts*
- ~80% of software organizations worldwide

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Level 2 - Repeatable

- *Basic* management processes, quality assurance and configuration control procedures in place
- Can repeat earlier successes
- Realistic project commitments based on results of previous projects
- Still has frequent quality problems
- *Stable planning and tracking*
- ~15% of software organizations worldwide

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Level 3 - Defined

- Documented, standardized, and integrated management and engineering processes
- Procedures are in place to insure they are followed
- Projects tailor organization's standard to develop own process
- Software Engineering Process Group (SEPG)
- *Stable foundation for software engineering and management*
- ~5% of software organizations worldwide

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Level 4 - Managed

- Quality and performance is measured using metrics and can be predicted
- Quality and productivity *quantitative* goals are established
- Exceptional cases are identified and addressed
- Challenge of new domains can be managed
- *Process is measured and operates within limits*
- < 1% of software organizations worldwide

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Level 5 - Optimizing

- Organization focuses on continuous process improvement
- Goal is to address and prevent problems by analyzing their cause in the process
- Process improvement is budgeted, planned, and part of the organization's process
- Identify and quickly transfer best practices
- Only a handful of organizations worldwide

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Why Five Levels?

- Reasonably represents historical phases in actual software organizations
- Reasonable measure of improvement from previous level
- Suggests interim goals and measures
- Prioritize improvements

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Key Process Areas (KPA)

- Issues to address to reach each maturity level
- Related activities for achieving goals

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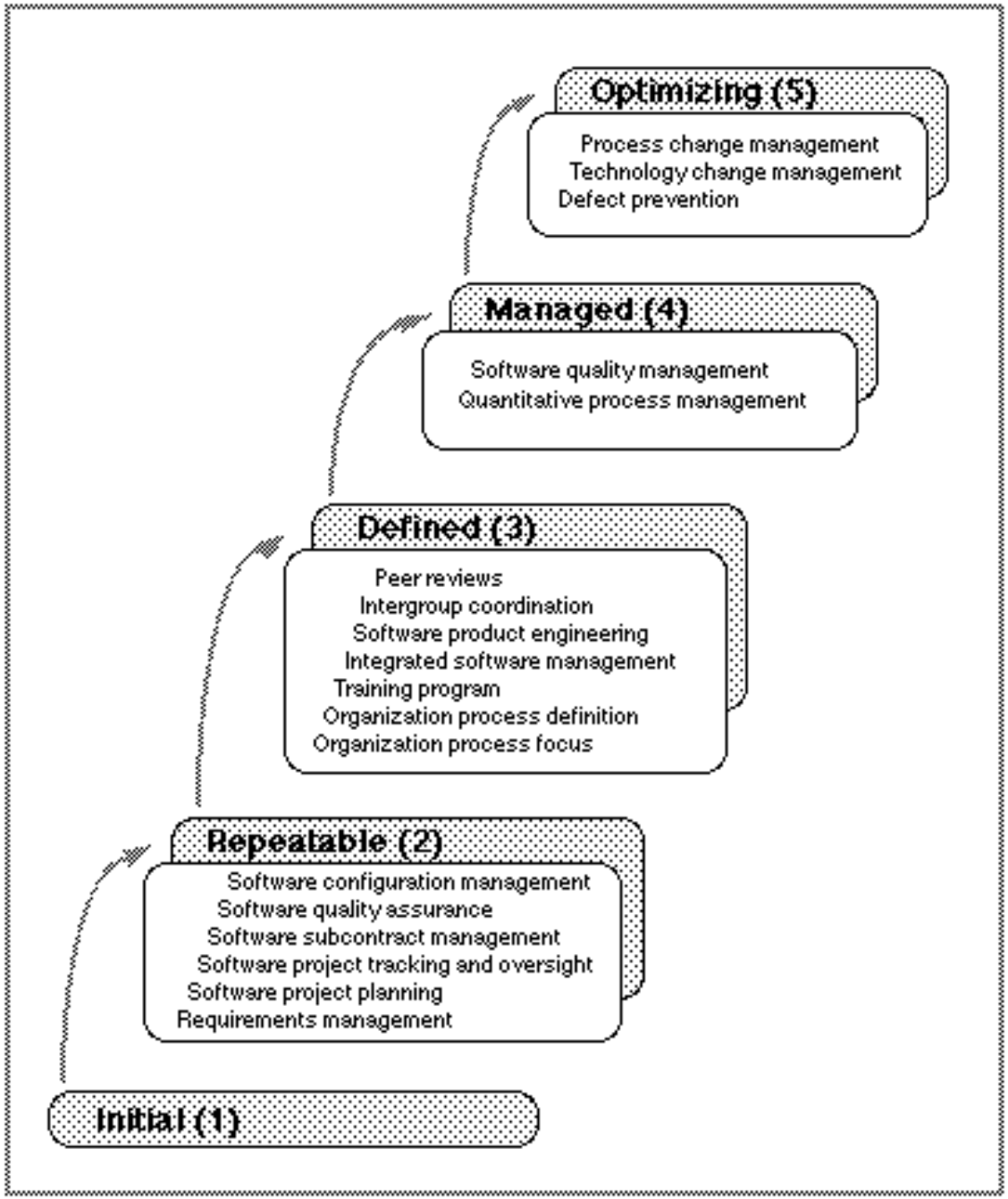

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Key Process Areas—Repeatable(2)

- Requirements management
- Software project planning
- Software project tracking and oversight
- Software quality assurance
- Software configuration management
- Software subcontract management

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Key Process Areas—Defined (3)

- Organization process focus
- Organization process definition
- Training program
- Integrated software management
- Software product engineering
- Intergroup coordination
- Peer reviews

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Key Process Areas—Managed (4)

- Quantitative process management
- Software quality management

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Key Process Areas—Optimized(5)

- Defect prevention
- Technology change management
- Process change management

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CMM outcomes

- Fewer project overruns
- Better cost prediction (dollars, time)
- Predicted performance improvements

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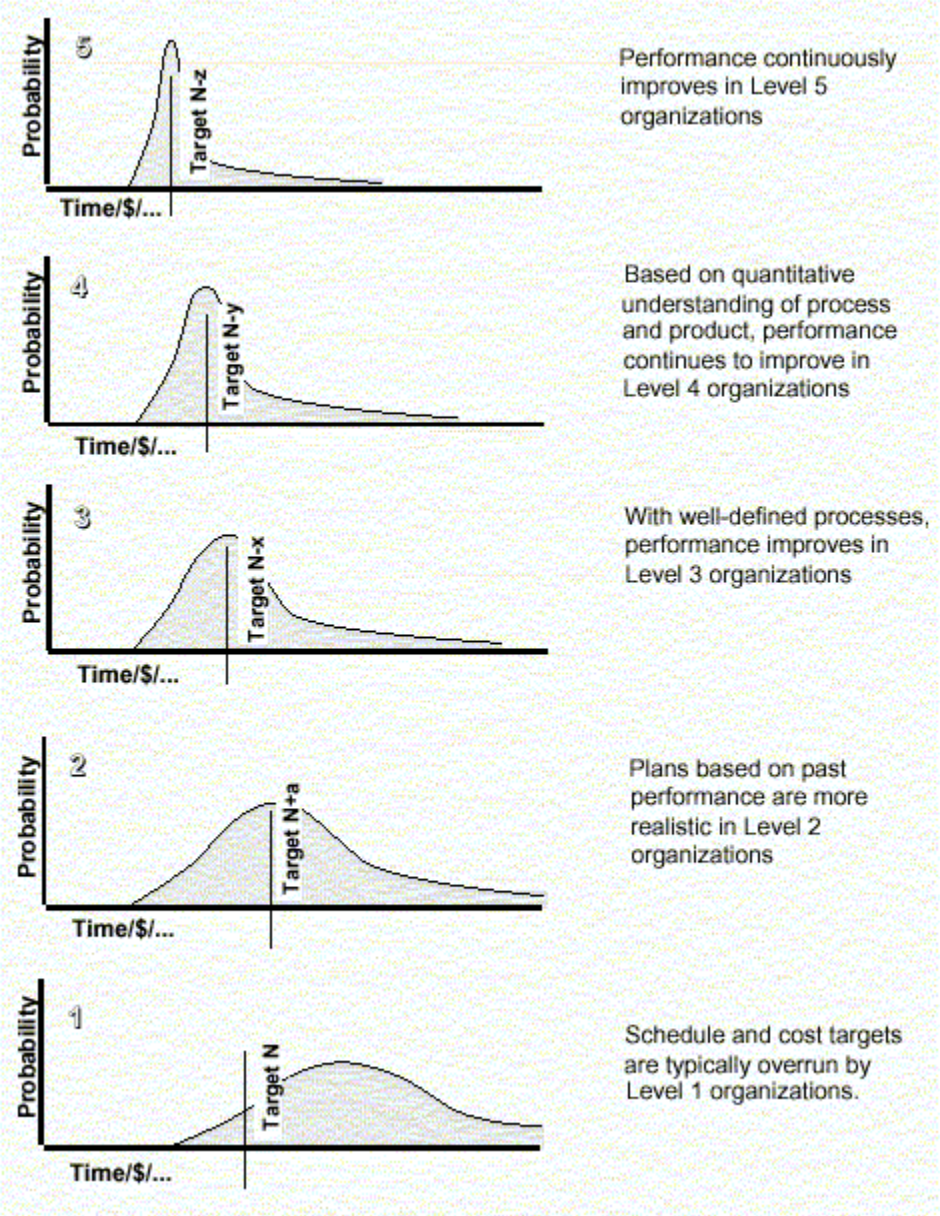

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Visibility

1. No process internals regularly visible
2. Process allows a few visible check points
3. Process allows many regular visible check points
4. Process is quantitatively measured at many check points
5. Processes replaced by better processes

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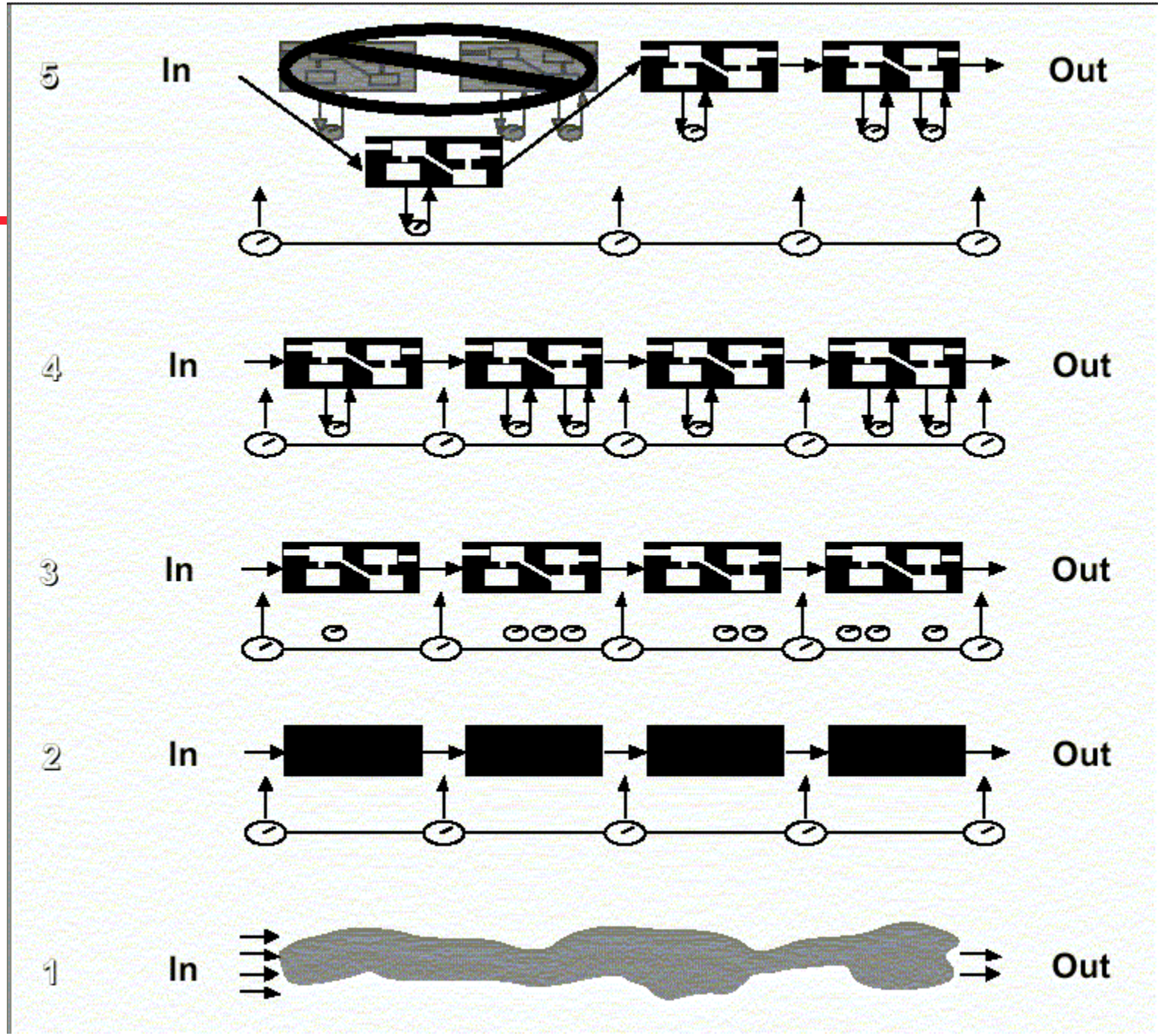

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CMM in practice

"Although much is written about the topic in qualitative terms, little quantitative information is available. In many ways, the engineering process is an informational 'black hole' -- it draws in money and resources like a magnet but little data emerges." (Howard Rubin)

- Only 2 DoD contractors and one government organization have released data documenting their return on investment for software process improvement

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CMM in practice

- Raytheon
  - 7.7:1 return on investment, savings of $4.48M
  - Elimination of $15.8M in rework costs
  - Twofold increase in productivity
- Hughes Aircraft
  - Initially Level 2, progressed to Level 3
  - ~$45K for assessment, ~$400K to improve
  - 5:1 ratio of ROI
  - Annual savings of approximately $2M
  - Decreased risk of missing cost and schedule estimates
  - Improved quality of work life (less overtime)
- Tinker Air Force Base
  - 6:1 ratio of ROI
  - Savings of $3.8M for $0.64M investment

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Validity of Published Data

- What's the baseline?
- Is the observed process improvement attributable to the CMM?
- Was the data obtained by comparing "Apples and Oranges"?

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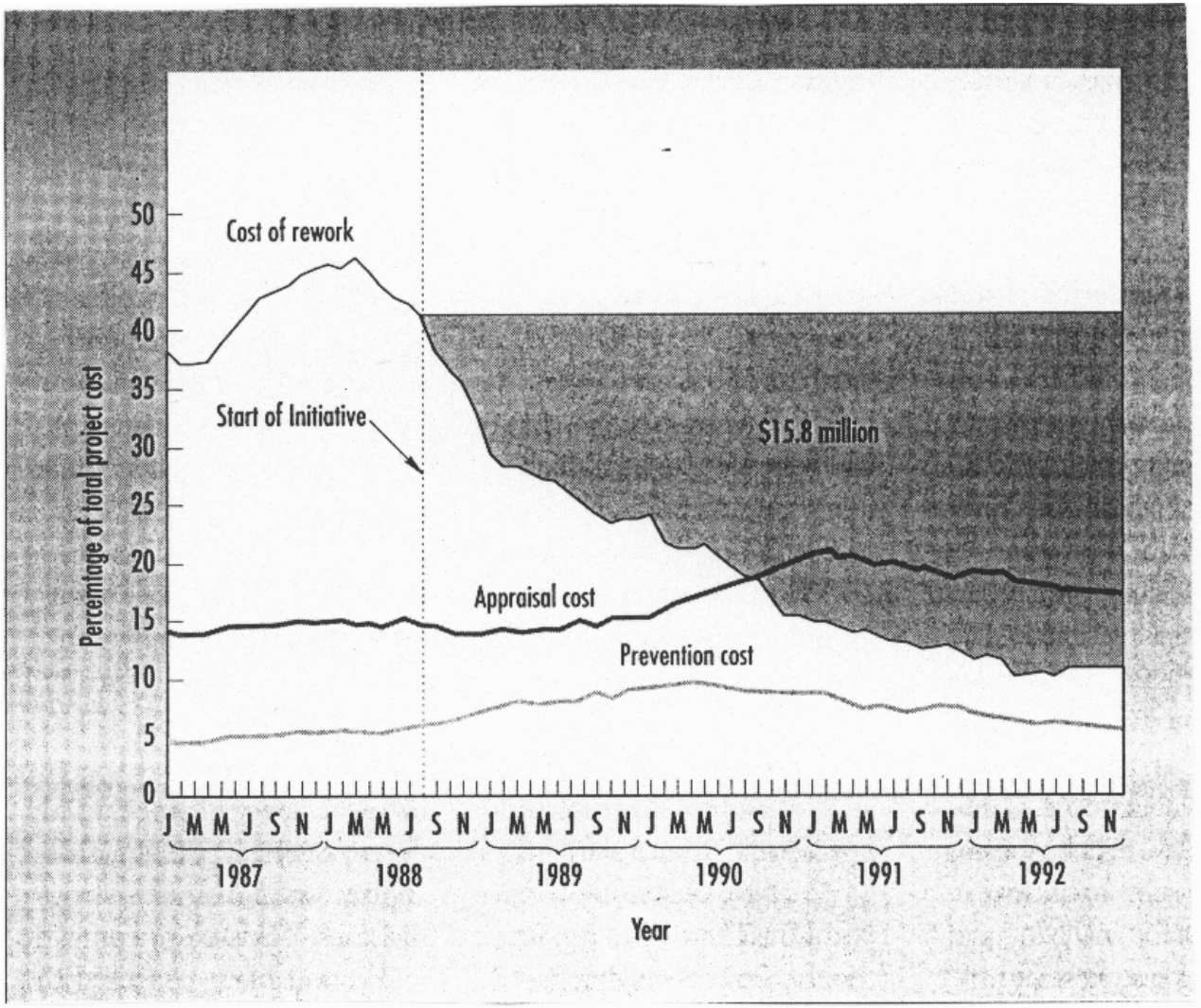
Savings at Raytheon



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Savings at Raytheon

- Cost increases and decreases
  - Fixing defects during design: 2.5 times increase
  - Fixing defects during coding: 1.75 times increase
  - Integration cost: decrease by 80%
  - Retesting cost: decrease by 50%

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Raytheon Productivity Data

- Measure: equivalent delivered source instructions per man-month
- Modified and reused LOC are weighted according to the relative effort of modification or reuse compared to new code
- Not scientifically accurate because of variations among the projects

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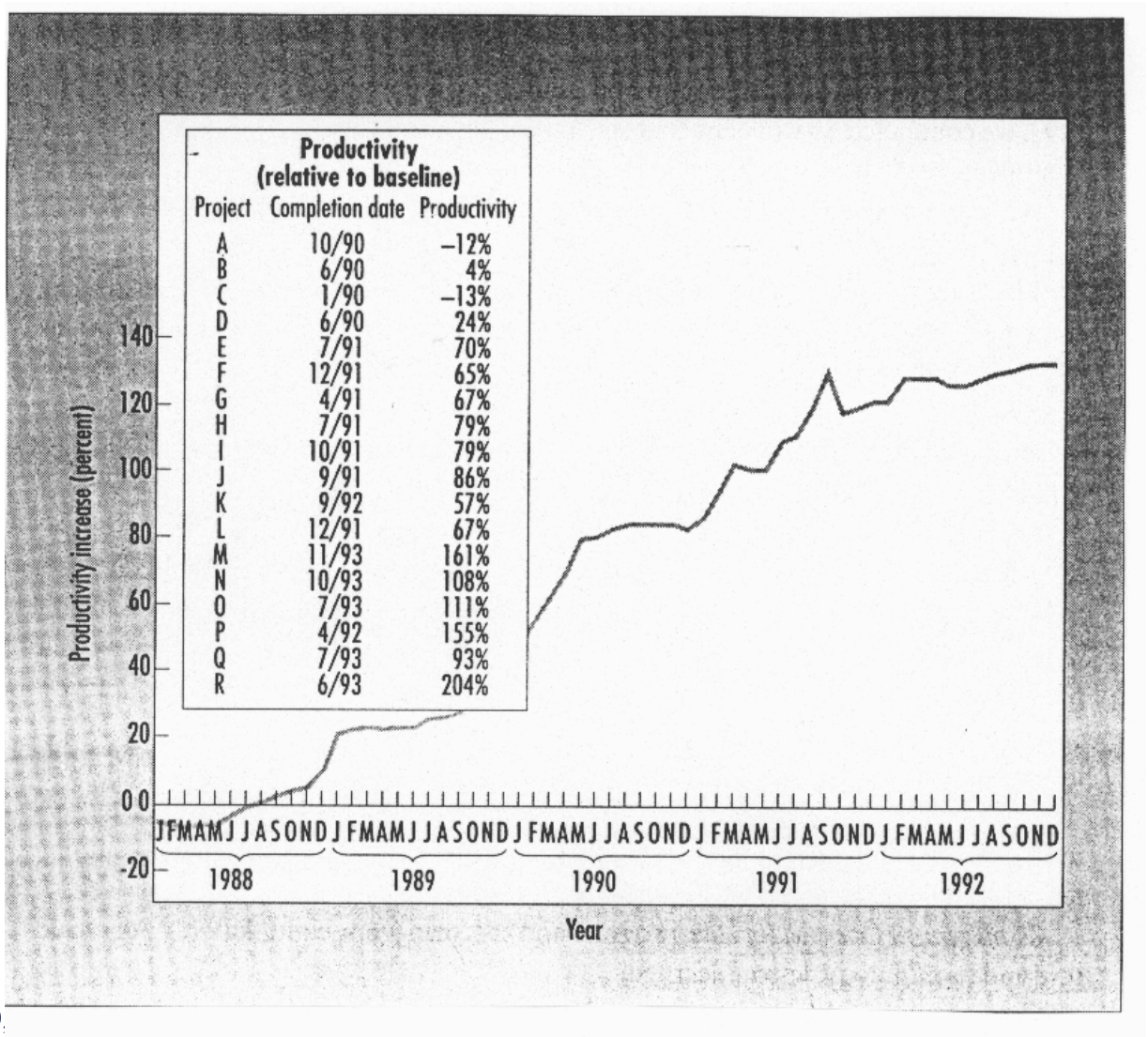
Raytheon Productivity Data



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Data from a wider range of US Industry

- Data from 35 companies and government agencies
- various levels of maturity
  - mostly Level 1-3, all organizations at Level 4 and 5 participated
- various geographical locations

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Cost of Process Improvement

Category	Measurement	Measured Cost Increases
Dollars	SW and HW costs	5% increase
Efforts	data collection cost	increased to 5-10% of effort
	cost of fixing design defects	increased from 0.75% to 2% of project cost
	cost of fixing code defects	increased from 2.5% to 4%
	cost of first-time testing	increased to 9-10% of effort
	inspection overhead	increased to 2% of development time

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Drawbacks of CMM

- CMM is not a “Silver Bullet”
- What do you think some drawbacks are?

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Drawbacks of CMM

- Lack of innovation?
  - CMM says what you need, not how to do it
  - Usually because processes done wrong
  - Processes are supposed to routinize mundane aspects of work so you can focus on interesting aspects
  - Do it right, and do it right once
  - Even Microsoft has well defined processes, estimates itself to be at Level 3

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Drawbacks of CMM (cont.)

- Two common complaints about CMM
  - Does not focus on good design
  - Does not focus on good people
  - However, these are not the goals of CMM!
- Other models have been developed
  - P-CMM (People Capability Maturity Model)
  - Team Capability Maturity Model
  - PSP - Personal Software Process

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Drawbacks of CMM (cont.)

- Describes what an organization should have, does not say how to get there
- Clearly defined process != good process
- Favors narrow maintenance processes over innovative ones
- Process Assessment flaws
  - Statistical problems, sparse coverage, process risk

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Drawbacks of CMM (cont.)

- Government may require at least Level 3 compliance for contractors
  - Private industry likely to follow suit
  - May lead to political problems
- May lead to ossification of software processes

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Drawbacks of CMM (cont.)

- Assembly-line process and control concepts are applicable to software
  - In manufacturing, majority of costs and risks are in replication
  - In software, majority of costs and risks are in design
  - Almost exact opposites!
- Even though in use, *still unproven*

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ISO 9000

- International Standard Organization (ISO) – ISO 9000 (1987, 1991)
- A series of 5 related standards that are applicable to a wide variety of industrial activities.
- Used for a wide range of industrial applications. (therefore not certainly a software standard)
- ISO 9001 Standard for quality system (closest related to software engineering).
- Like the CMM the ISO 9000 emphasizes measurement. Both models stress on documenting the process in word and pictures.
- It has been reported that at least two level 1 organization have been certified as compliant with ISO 9000.

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SPICE

- Spice is intended to extend and improve the CMM and ISO 9000 models.
- Differences include that Spice provides a framework for assessment methods, but does not lay down a specific method.
- Spice provides a separate assessment of each component of the overall process (analysis, specification, configuration management, etc…)

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Conclusions

- Good processes are essential
- We are still learning about good processes for software development
- CMM was developed to assess and to give organizations a framework to improve
- Despite some flaws, CMM is a significant contribution to the software industry
- CMMv2 in progress at http://www.sei.cmu.edu/

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