Software Quality Assurance

(Lecture 14)

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Organization of this Lecture:

- Introduction Quality Engineering.
- Quality control and Quality Assurance
- ISO 9000
- SEI CMM
- Summary

Introduction

- Traditional definition of quality:
  - fitness of purpose,
    - a quality product does exactly what the users want it to do.

Fitness of purpose

- For software products,
  - fitness of purpose:
    - satisfaction of the requirements specified in SRS document.

Fitness of purpose

- A satisfactory definition of quality for many products:
  - a car, a table fan, a food mixer, microwave oven, etc.
- But, not satisfactory for software products.

Introduction

- Consider a software product:
  - functionally correct,
    - i.e. performs all functions as specified in the SRS document,
  - but has an almost unusable user interface.
    - cannot be considered as a quality product.

Introduction

- Another example:
  - a product which does everything that users want.
  - but has an almost incomprehensible and unmaintainable code.

Modern view of quality

- Associates several quality factors with a software product :
  - Correctness
  - Reliability
  - Efficiency (includes efficiency of resource utilization)
  - Portability
  - Usability
  - Reusability
  - Maintainability

Correctness

- A software product is correct,
  - if different requirements as specified in the SRS document have been correctly implemented.
  - Accuracy of results.

Portability

- A software product is said to be portable,
  - if it can be easily made to work in different operating systems,
  - in different machines,
  - with other software products, etc.

Reusability

- A software product has good reusability,
  - if different modules of the product can easily be reused to develop new products.

Usability

- A software product has good usability,
  - if different categories of users (i.e. both expert and novice users) can easily invoke the functions of the product.

Maintainability

- A software product is maintainable,
  - if errors can be easily corrected as and when they show up,
  - new functions can be easily added to the product,
  - functionalities of the product can be easily modified, etc.

Software Quality Management System

- Quality management system (or quality system):
  - principal methodology used by organizations to ensure that the products have desired quality.

Quality system

- A quality system consists of the following:
  - Managerial Structure
  - Individual Responsibilities.
- Responsibility of the organization as a whole.

- The quality system encompass the following ;
- Auditing of projects
- Review of the quality system
- Development of standard
- Production of reports for the top management summarizing the effectiveness of quality system.

Quality system

- Every quality conscious organization has an independent quality department:
  - performs several quality system activities.
  - needs support of top management.
  - Without support at a high level in a company,
    - many employees may not take the quality system seriously.

Quality System Activities:

- Auditing of projects
- Development of:
  - standards, procedures, and guidelines, etc.
- Production of reports for the top management
  - summarizing the effectiveness of the quality system in the organization.
- Review of the quality system itself.

Quality system

- A good quality system must be well documented.
  - Without a properly documented quality system,
    - application of quality procedures become ad hoc,
    - results in large variations in the quality of the products delivered.

Quality system

- An undocumented quality system:
  - sends clear messages to the staff about the attitude of the organization towards quality assurance.
- International standards such as ISO 9000 provide:
  - guidance on how to organize a quality system.

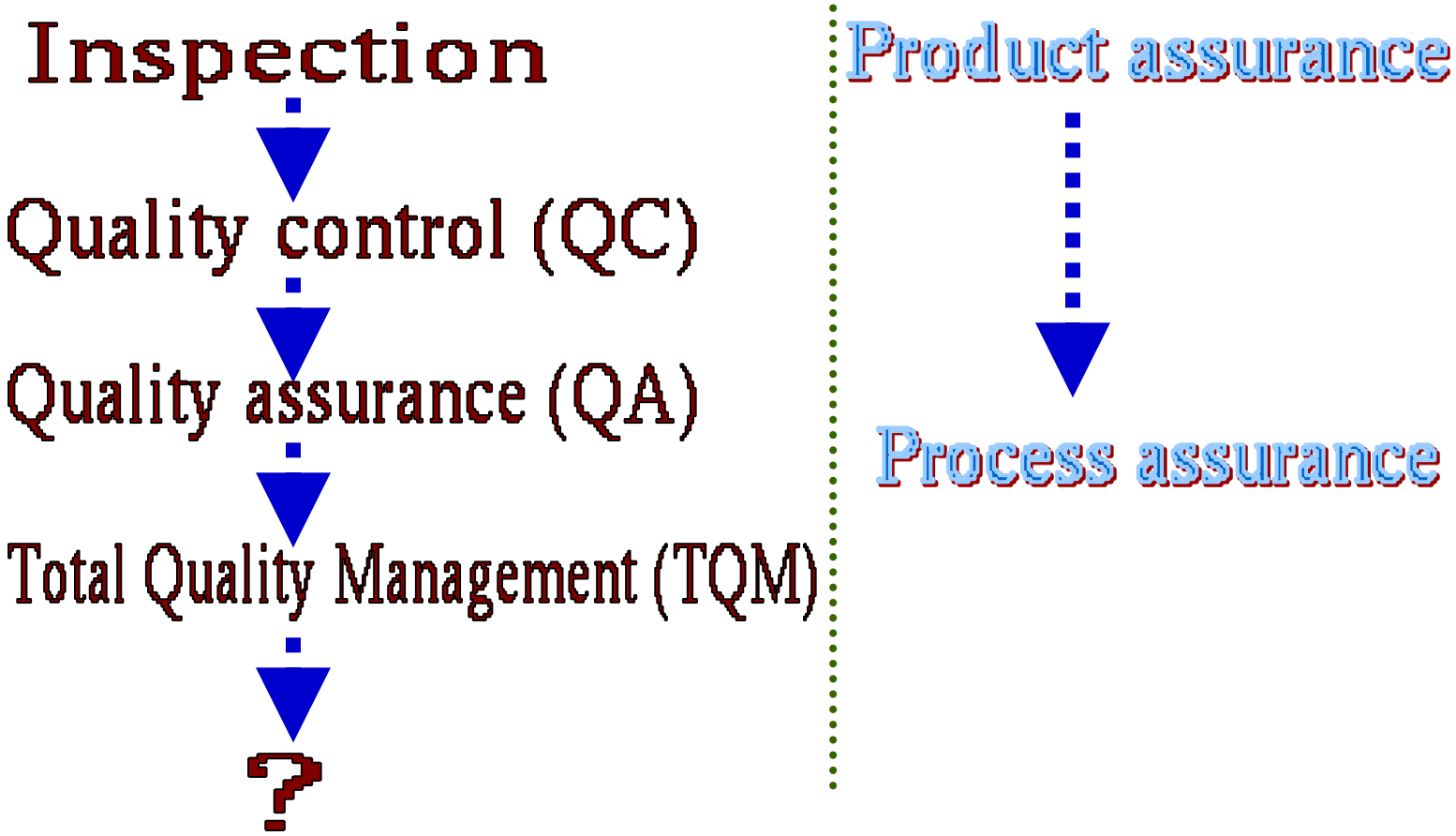
Evolution of Quality Systems

- Quality systems have evolved:
  - over the last five decades.
- Prior to World War II,
  - way to produce quality products:
    - inspect the finished products
    - eliminate defective products.

Evolution of Quality Systems

- Since that time,
  - quality systems of organizations have undergone
    - four stages of evolution.

Evolution of Quality Systems



Evolution of Quality Systems

- Initial product inspection method :
  - gave way to quality control (QC).
- Quality control:
  - not only detect the defective products and eliminate them
  - but also determine the causes behind the defects.

Quality control (QC)

- Quality control aims at correcting the causes of errors:
  - not just rejecting defective products.
- Statistical quality control
  - quality of the output of the process is inferred using statistical methods
  - in stead of inspection or testing of all products

Quality control (QC)

- The next breakthrough,
  - development of quality assurance principles

Quality assurance

- Basic premise of modern quality assurance:
  - if an organization's processes are good and are followed rigorously,
    - the products are bound to be of good quality.

Quality assurance

- All modern quality paradigms include:
  - guidance for recognizing, defining, analyzing, and improving the production process.

Total quality management (TQM)

- Advocates:
  - continuous process improvements through process measurements.

Business Process reengineering

- A term related to TQM.
- Process reengineering goes a step further than quality assurance:
  - aims at continuous process improvement.

Business Process reengineering

- Our focus is reengineering of the software process.
- Whereas BPR aims at reengineering the way business is carried out in any organization
  - not just software development organizations.

Total quality management (TQM)

- TQM goes beyond documenting processes
  - optimizes them through redesign.
- Over the years the quality paradigm has shifted:
  - from product assurance to process assurance.

ISO 9000

- ISO (International Organization for Standardization):
  - a consortium of 63 countries established to formulate and foster standardization.
- ISO published its 9000 series of standards in 1987.

What is ISO 9000 Certification?

- ISO 9000 certification:
  - serves as a reference for contract between independent parties.
- The ISO 9000 standard:
  - specifies guidelines for maintaining a quality system.

What is ISO 9000 Certification?

- ISO 9000 specifies:
  - guidelines for repeatable and high quality product development.
  - Also addresses organizational aspects
    - responsibilities, reporting, procedures, processes, and resources for implementing quality management.

ISO 9000

- A set of guidelines for the production process.
  - not directly concerned about the product it self.
  - a series of three standards:
    - ISO 9001, ISO 9002, and ISO 9003.

ISO 9000

- Based on the premise:
  - if a proper process is followed for production:
    - good quality products are bound to follow.

ISO 9001:

- Applies to:
  - organizations engaged in design, development, production, and servicing of goods.
  - applicable to most software development organizations.

ISO 9002:

- ISO 9002 applies to:
  - organizations who do not design products:
    - but are only involved in production.
- Examples of this category of industries:
  - steel or car manufacturing industries
  - buy the product and plant designs from external sources:
    - only manufacture products.
  - not applicable to software development organizations.

ISO 9003

- ISO 9003 applies to:
  - organizations involved only in installation and testing of the products.

ISO 9000 for Software Industry

- ISO 9000 is a generic standard:
  - applicable to many industries,
    - starting from a steel manufacturing industry to a service rendering company.
- Many clauses of ISO 9000 documents:
  - use generic terminologies
  - very difficult to interpret them in the context of software organizations.

Software vs. other industries

- Very difficult to interpret many clauses for software industry:
  - software development is radically different from development of other products.

Software vs. other industries

- Software is intangible
  - therefore difficult to control.
    - It is difficult to control anything that we cannot see and feel.
  - In contrast, in a car manufacturing unit:
    - we can see a product being developed through stages such as fitting engine, fitting doors, etc.
    - one can accurately tell about the status of the product at any time.
  - Software project management is an altogether different ball game.

Software vs. other industries

- During software development:
  - the only raw material consumed is data.
- For any other product development:
  - Lot of raw materials consumed
    - e.g. Steel industry consumes large volumes of iron ore, coal, limestone, etc.
- ISO 9000 standards have many clauses corresponding to raw material control .
    - not relevant to software organizations.

Software vs. other industries

- Radical differences exist between software and other product development,
  - difficult to interpret various clauses of the original ISO standard in the context of software industry.

ISO 9000 Part-3

- ISO released a separate document called ISO 9000 part-3 in 1991
  - to help interpret the ISO standard for software industry.
- At present,
  - official guidance is inadequate

Why Get ISO 9000 Certification?

- Several benefits:
  - Confidence of customers in an organization increases
    - if organization qualified for ISO 9001 certification.
    - This is especially true in the international market.

Why Get ISO 9000 Certification?

- Many international software development contracts insist:
  - development organization to have ISO 9000 certification.

Why Get ISO 9000 Certification?

- Requires:
  - a well-documented software production process to be in place.
  - contributes to repeatable and higher quality software.
- Makes development process:
  - focussed, efficient, and cost-effective

Why Get ISO 9000 Certification?

- Points out the weakness of an organizations:
  - recommends remedial action.
- Sets the basic framework:
  - for development of an optimal process and TQM.

How to Get ISO 9000 Certification?

- An organization intending to obtain ISO 9000 certification:
  - applies to a ISO 9000 registrar for registration.
- ISO 9000 registration process consists of several stages.

How to Get ISO 9000 Certification?

- Application stage:
  - Applies to a registrar for registration.
- Pre-assessment:
  - the registrar makes a rough assessment of the organization.

How to Get ISO 9000 Certification?

- Document review and adequacy audit:
  - process and quality-related documents.
  - the registrar reviews the documents
  - makes suggestions for improvements.

How to Get ISO 9000 Certification?

- Compliance audit: the registrar checks
  - whether the suggestions made by it during review have been complied.

How to Get ISO 9000 Certification?

- Registration:
  - The registrar awards ISO 9000 certificate after successful completions of all previous phases.
- Continued surveillance:
  - The registrar continues monitoring the organization periodically.

ISO 9000 Certification

- An ISO certified organization
  - can use the certificate for corporate advertizements
  - cannot use the certificate to advertize products.
    - ISO 9000 certifies organization's process
    - not any product of the organization.
  - An organization using ISO certificate for product advertizements:
    - risks withdrawal of the certificate.

Summary of ISO 9001 Requirements

- **Management responsibility(4.1):**
  - Management must have an effective quality policy.
  - The responsibility and authority of all those whose work affects quality:
    - must be defined and documented.

Management responsibility(4.1)

- Responsibility of the quality system.
  - independent of the development process,
  - can work in an unbiased manner.
- The effectiveness of the quality system:
  - must be periodically by audited.

Quality system (4.2) and contract reviews (4.3):

- A quality system must be maintained and documented.
- Contract reviews (4.3):
  - Before entering into a contract, an organization must review the contract
    - ensure that it is understood,
    - organization has the capability for carrying out its obligations.

Design control (4.4):

- The design process must be properly controlled,
  - this includes controlling coding also.
- A good configuration control system must be in place.

Design control (4.4):

- Design inputs must be verified as adequate.
- Design must be verified.
- Design output must be of required quality.
- Design changes must be controlled.

Document control (4.5):

- Proper procedures for
  - document approval, issue and removal.
- Document changes must be controlled.
  - use of some configuration management tools is necessary.

Purchasing (4.6):

- Purchased material, including bought-in software:
  - must be checked for conforming to requirements.

Purchaser Supplied Products (4.7):

- Material supplied by a purchaser,
  - for example,
    - client-provided software must be properly managed and checked.

Product Identification (4.8):

- The product must be identifiable at all stages of the process.
  - In software development context this means configuration management.

Process Control (4.9) :

- The development must be properly managed.
- Quality requirements must be identified in a quality plan.

Inspection and Testing (4.10) :

- In software terms this requires effective testing i.e.,
  - unit testing, integration testing and system testing.
- Test records must be maintained.

Inspection, measuring and test equipment(4.11):

- If integration, measuring, and test equipments are used,
  - must be properly maintained and calibrated.

Control of nonconforming product (4.13) :

- In software terms,
  - keeping untested or faulty software out of released product,
    - or other places whether it might cause damage.

Corrective Action (4.14) :

- This is both about correcting errors when found,
  - investigating why they occurred
  - improving the process to prevent further occurrences.
- If an error reoccurs despite the quality system,
  - the system needs improvement.

Handling (4.15) and Quality audits (4.17):

- Handling (4.15) Deals with:
  - storage, packing, and delivery of the software product.
- Quality Audits (4.17) :
  - quality system audit must be carried out to ensure its effectiveness.

Training (4.18) :

- Training needs must be identified and met.
- Most items of ISO standard
  - are largely common sense.

Salient features of ISO 9001 requirements:

- All documents concerned with the development of a software product
  - should be properly managed, authorized, and controlled.
- Proper plans should be prepared
  - progress against these plans should be monitored.

Salient features of ISO 9001 requirements:

- Important documents independently checked and reviewed:
  - for effectiveness and correctness.
- The product should be tested :
  - against specification.
- Several organizational aspects:
  - e.g., management reporting of the quality team.

Shortcomings of ISO 9001 Certification (1)

- ISO 9000 requires a production process to be adhered to:
  - but does not guarantee the process to be of high quality.
  - Does not give any guideline for defining an appropriate process.

Shortcomings of ISO 9001 Certification (2)

- ISO 9000 certification process
  - not fool-proof
  - no international accredition agency exists.
  - likely variations in the norms of awarding certificates:
    - among different accredition agencies and among the registrars.

Shortcomings of ISO 9001 Certification (3)

- Organizations qualifying for ISO 9001 certification:
  - tend to downplay domain expertise.
  - tend to believe that since a good process is in place,
    - any engineer is as effective as any other engineer in doing any particular activity relating to software development.

Shortcomings of ISO 9001 Certification (4)

- In manufacturing industry
  - clear link between process quality and product quality
  - once a process is calibrated:
    - can be run again and again producing quality goods
- Software development is a creative process:
  - individual skills and experience is significant

Shortcomings of ISO 9001 Certification (5)

- Many areas of software development are very specialized:
  - special expertize and experience (domain expertize) required.
- ISO 9001
  - does not automatically lead to continuous process improvement,
  - does not automatically lead to TQM.

Shortcomings of ISO 9001 Certification (6)

- ISO 9001 addresses mostly management aspects.
- Techniques specific to software development have been ignored
  - Configuration management
  - Reviews
  - Release builds
  - Problem Notification system
  - Intranets

SEI Capability Maturity Model

- Developed by Software Engineering Institute (SEI) of the Carnegie Mellon University, USA:
  - to assist the U.S. Department of Defense (DoD) in software acquisition.
  - The rationale was to include:
    - likely contractor performance as a factor in contract awards.

SEI Capability Maturity Model

- Major DoD contractors began CMM-based process improvement initiatives:
  - as they vied for DoD contracts.
- SEI CMM helped organizations:
  - Improve quality of software they developed
  - Realize adoption of SEI CMM model had significant business benefits.
- Other organizations adopted CMM.

SEI Capability Maturity Model

- In simple words,
  - CMM is a model for apprising the software process maturity of a contractor into different levels.
  - Can be used to predict the most likely outcome to be expected from the next project that the organization undertakes.

SEI Capability Maturity Model

- Can be used in two ways:
  - Capability evaluation
  - Software process assessment.

Capability Evaluation

- Provides a way to **assess** the software process capability of an organization
  - Helps in selecting a contractor
  - Indicates the likely contractor performance

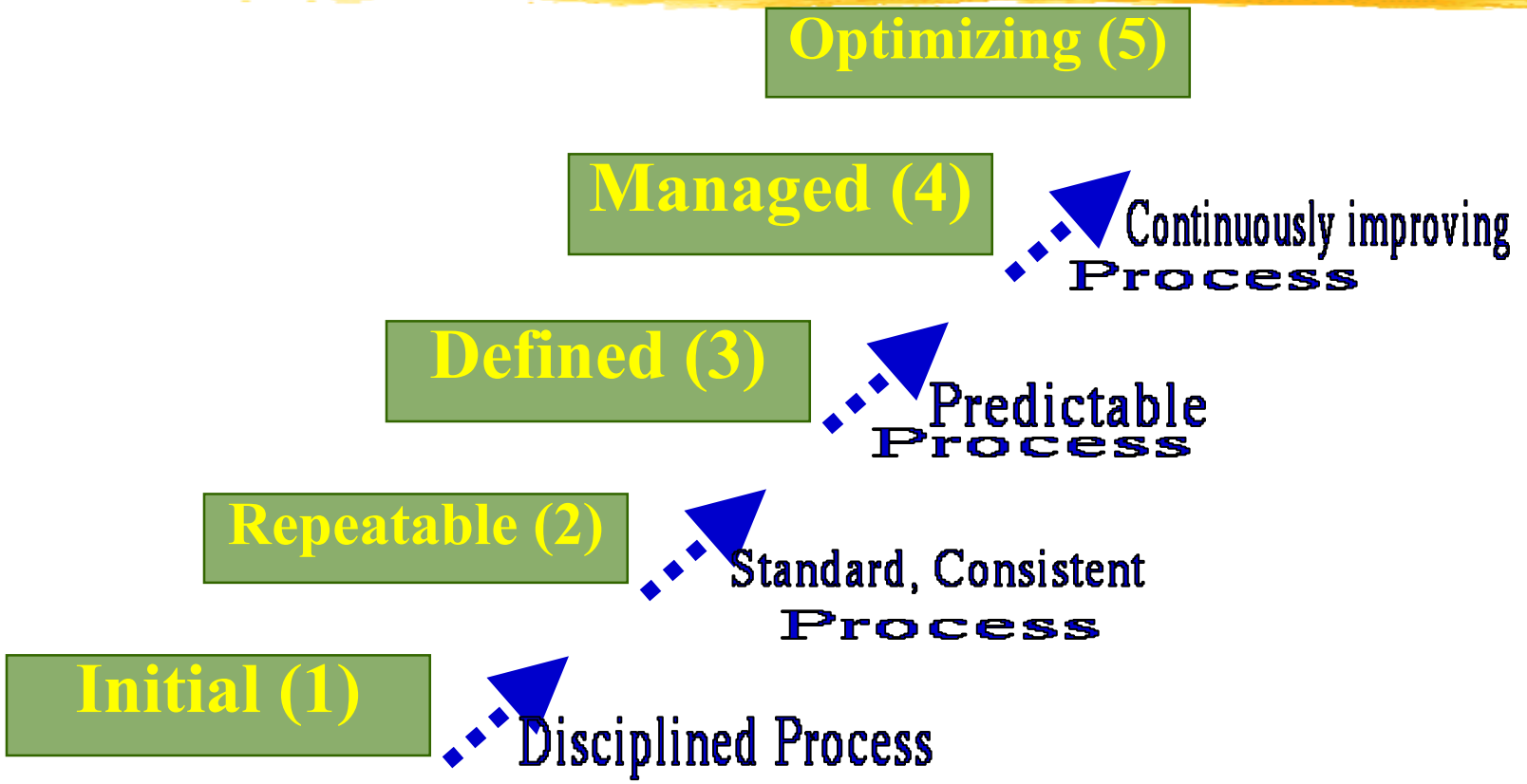
Software Process Assessment

- Used by an organization to assess its current process:
  - Suggests ways to improve the process capability.
  - This type of assessment is for purely internal use.

SEI Capability Maturity Model

- The SEI CMM classifies software development industries into:
  - Five maturity levels.
  - Stages are ordered so that improvements at one stage provide foundations for the next
  - Based on the pioneering work of Philip Crosby

SEI Capability Maturity Model



Level 1: (Initial)

- Organization operates
  - without any formalized process or project plans
- An organization at this level is characterized by
  - ad hoc and often chaotic activities.

Level 1: (Initial)

- Software production processes are not defined,
  - different engineers follow their own process
  - development efforts become chaotic.
  - The success of projects depend on individual efforts and heroics.

Level 2: (Repeatable)

- Basic project management practices
  - tracking cost, schedule, and functionality are followed.
- Size and cost estimation techniques
  - function point analysis, COCOMO, etc. used.
- Production process is ad hoc
  - not formally defined
  - also not documented.

Level 2: (Repeatable)

- Process used for different projects might vary between projects:
  - earlier success on projects with similar applications can be repeated.
  - Opportunity to repeat process exist when a company produces a family of products.

Level 3: (Defined)

- Management and development activities:
  - defined and documented.
  - Common organization-wide understanding of activities, roles, and responsibilities.

Level 3: (Defined)

- The process though defined,
  - process and product qualities are not measured.
- ISO 9001 aims at achieving this level.

Level 4: (Managed)

- Quantitative quality goals for products are set.
- Software process and product quality are measured:
  - The measured values are used to control the product quality.
  - Results of measurement used to evaluate project performance
    - rather than improve process.

Level 4: (Managed)

- Organization sets quantitative quality goals
- World-wide about 100 organizations assessed at this level.

Level 5: (Optimizing)

- Statistics collected from process and product measurements are analyzed:
  - continuous process improvement based on the measurements.
    - Known types of defects are prevented from recurring by tuning the process
    - lessons learned from specific projects incorporated into the process

Level 5: (Optimizing)

- Identify best software engineering practices and innovations:
  - tools, methods, or process are identified
  - transferred throughout the organization
- World-wide about 50 organizations have been assessed at this level.

Key Process Areas

- Each level is associated with a key process area (KPA) identifies
  - where an organization at the previous level must focus to reach this level

Level 2 KPAs

- Software project planning
  - Size, cost, schedule.
  - project monitoring
- Configuration management
- Subcontract management

Level 3 KPAs

- Process definition and documentation
- Reviews
- Training program

Level 4 KPAs

- Quantitative measurements
- Process management

Level 5 KPAs

- Defect prevention
- Technology change management
- Process change management

Comparison between ISO 9001 and SEI CMM

- ISO 9001 awarded by an international standards body
  - can be quoted in official documents and communications
- SEI CMM assessment is purely for internal use.

Comparison between ISO 9001 and SEI CMM

- SEI CMM was developed specifically for software industry:
  - addresses many issues specific to software industry.
- SEI goes beyond quality assurance
  - aims for TQM
  - ISO 9001 correspond to SEI level 3.

Comparison between ISO 9001 and SEI CMM

- SEI CMM provides a list of key areas
  - on which to focus to take an organization from one level to the other
- Provides a way for gradual quality improvements over several stages.
  - e.g trying to implement a defined process before a repeatable process:
    - counterproductive as managers are overwhelmed by schedule and budget pressure.

Remarks on Quality Model Usage

- Highly systematic and measured approach to software development process suits certain circumstances
  - negotiated software, safety-critical software, etc
- What about small organizations?
  - Typically handle applications such as internet, e-comm.
  - without an established product range,
  - without revenue base, experience on past projects, etc.
  - CMM may be incompatible

Small Organizations

- Small organizations tend to believe:
  - We are all competent people hired to do a job, we can't afford training
  - We all communicate with one another
    - Osmosis works because we are so close
  - We are all heroes
    - We do what needs to be done
    - Therefore rules do not apply to us

Small Organizations

- Often have problems:
  - Undocumented requirements
  - Inexperienced managers
  - Documenting the product
  - Resource allocation
  - Training
  - Peer reviews

Small Organizations

- A two week CMM-based appraisal is probably excessive:
- Small organizations need to operate more efficiently at lower levels of maturity
  - Must first fluorish if eventually they are to mature

Personal Software Process (PSP)

- Based on the work of Humphrey
- PSP is a scaled down version of industrial software process
  - suitable for individual use
- Even CMM assumes that engineers use effective personal practices

Personal Software Process (PSP)

- A process is the set of steps for doing a job
- The quality and productivity of an engineer
  - largely determined by his process
- PSP is framework that
  - helps software engineers to measure and improve the way they work.

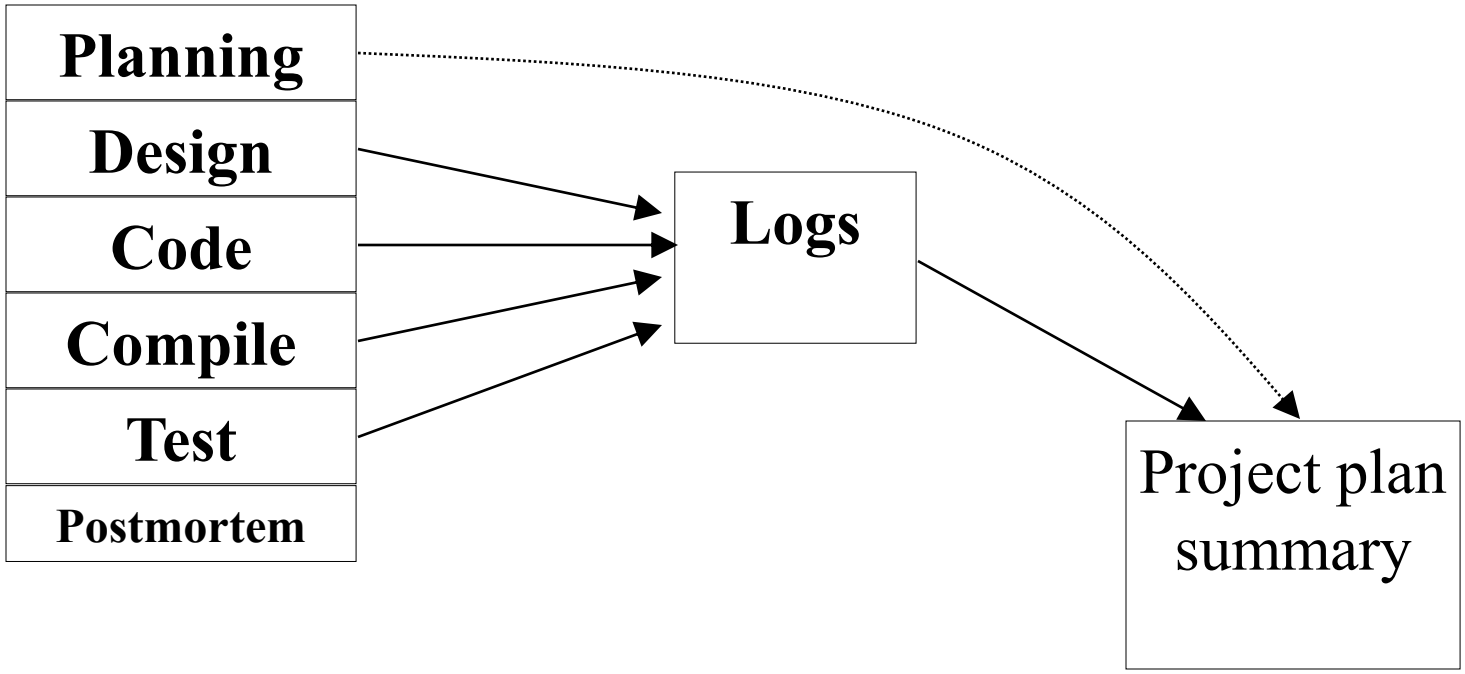
Personal Software Process (PSP)

- Helps developing personal skills and methods
  - Estimating and planning method
  - Shows how to track performance against plans
  - Provides a defined process
    - can be fine tuned by individuals
    - Recognizes that a process for individual use is different from that necessary for a team project.

Time Management

- Track the way you spend time
  - Boring activities seem longer then actual
  - Interesting activities seem short
- Record time for
  - Designing
  - Writing code
  - Compiling
  - Testing

Personal Software Process (PSP)



PSP-Planning

- Problem definition
- Estimate max, min, and total LOC
- Determine minutes/LOC
- Calculate max,min, and total development times
- Enter the plan data in project plan summary form
- record the planned time in Log

PSP-Design

- Design the program
- Record the design in specified format
- Record the Design time in time recording log

PSP-Code

- Implement the design
- Use a standard format for code text
- Record the coding time in time recording log

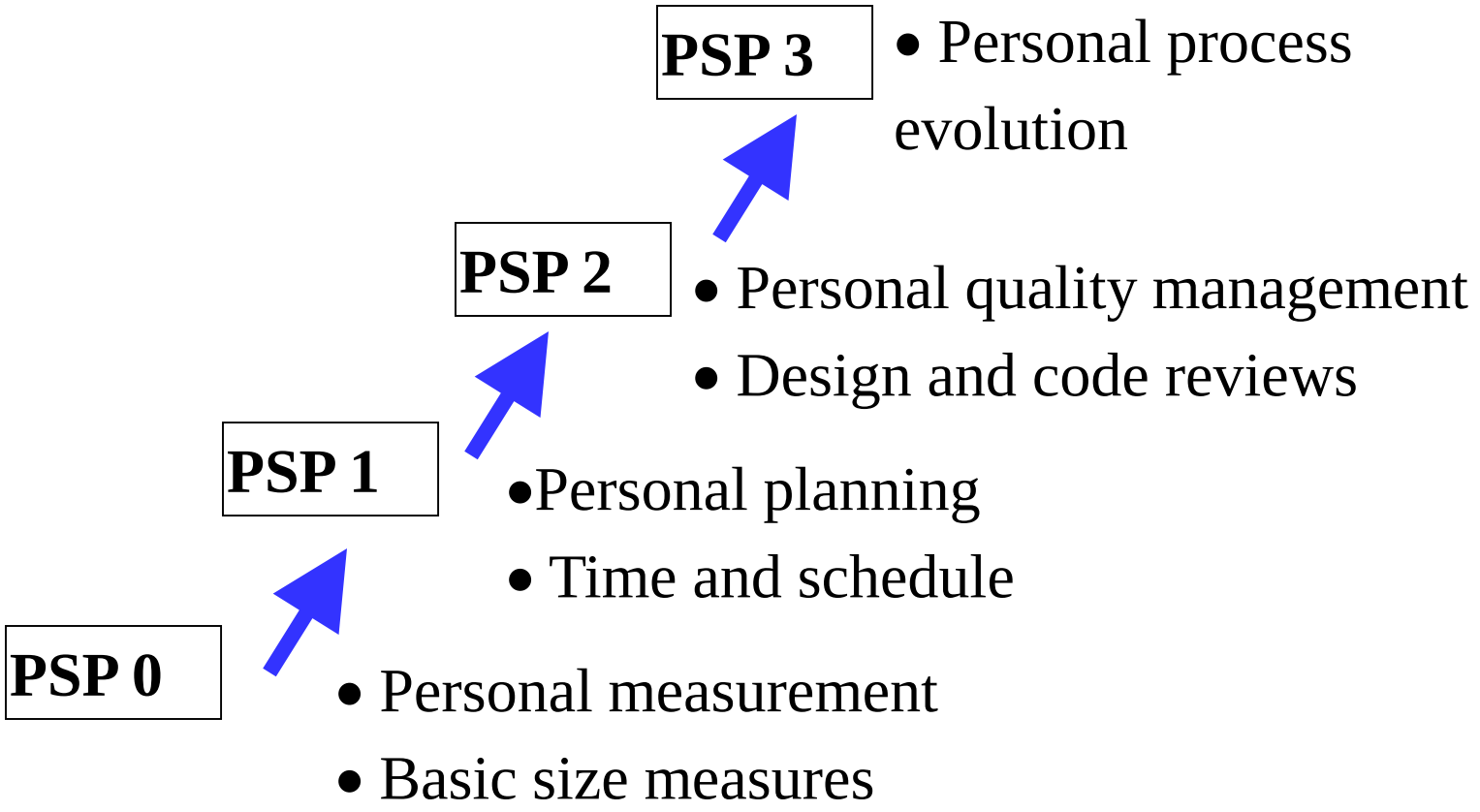
PSP-Compile

- Compile the program
- Fix all the defects
- Record compile time in time recording log

PSP-Test/Postmortem

- Test
  - Test the program
  - Fix all the defects found
  - Record testing time in time recording log
- Postmortem
  - Complete project plan summary form with actual time and size data
  - Record postmortem time in time record

Personal Software Process (PSP)



Six Sigma

- Six sigma is a quantitative approach to eliminate defects
  - Applicable to all types of industry - from manufacturing, product development, to service
- The statistical representation of Six Sigma quantitatively describes
  - how a process is performing

Six Sigma

- To achieve six sigma
  - a process must not produce more than 3.4 defects per million opportunities.
  - 5 Sigma -> 230 defects per million
  - 4 Sigma -> 6210 defects per million
- Six sigma methodologies
  - DMAIC (Define, Measure, Analyze, Improve, Control)
  - DMADV: (Define, Measure, Analyze, Design, Verify)

Six Sigma Methodologies

- The methodologies are implemented by Green belt and Black belt workers
  - Supervised by Master black belt worker
- Pareto Chart:
  - Simple bar chart to represent defect data
  - Identify the problems that occurs with greatest frequency
    - or incur the highest cost

Summary

- Evolution of quality system:
  - product inspection
  - quality control
  - quality assurance
  - total quality management (TQM)
- Quality paradigm change:
  - from product to process

Summary

- ISO 9000:
  - basic premise:
    - if a good process is followed
    - good products are bound to follow
  - provides guidelines for establishing a quality system.

Summary

- ISO 9000
  - series of three standards
    - 9001, 9002, and 9003
  - 9001 is applicable to software industry

Summary

- SEI CMM
  - developed specially for software industry
  - classifies software organizations into five categories.
    - According to the maturity of their development process.

Current Trends

- Many organizations have already tuned their process for
  - Budget,
  - Schedule, and
  - Quality product.
- Competition is challenging them to:
  - Reduce time for delivery
  - Adopt Six-Sigma methodology