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Six Sigma & Software/Systems Process Improvement

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Sponsored by the U.S. Department of Defense

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Outline / Objectives

Six Sigma Overview

Applications Survey

Initiative Synergy

Illustration

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Six Sigma Is…

A Philosophy

A Metric

An Improvement Framework

Six Sigma Philosophy

Improve customer satisfaction by reducing and eliminating defects

Greater Profits

What is a Defect?

Six Sigma:

- Any product, service, or process variation which prevents meeting the needs of the customer and/or which adds cost, whether or not it is detected.

Personal Software Process[SM]:

- Defects or faults are the result of errors or mistakes. At a minimum, count a defect every time the program is changed during compile or test, where the change might be one character or multiple statements

[Humphrey 95]

[SM]Personal Software Process and PSP are service marks of Carnegie Mellon University.

Six Sigma Metrics

"3.4 ppm" – the most-cited metric

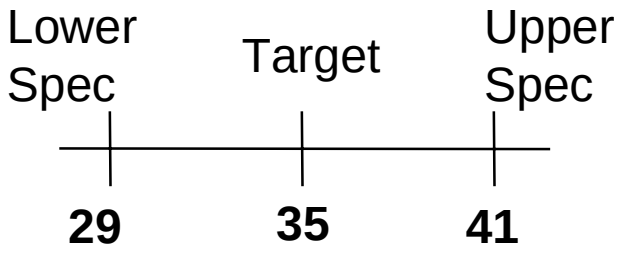
Other Measures

- Defect Rate, parts per million (ppm)
- Sigma Level
- Defects per Unit (dpu)
- Defects per Million Opportunities (dpmo)
- Yield

"3.4" and "Sigma" Metrics 1

New Car Buyer's target:

- 35 miles per gallon (mpg)
- 29-41 mpg acceptable



Two Choices:

Car 1

35 +/- 2 mpg

(35-29) / 2 = 3
(41-35) / 2 = 3

3 Sigma

~3/1000 outside limits

Car 2

35 +/- 1 mpg

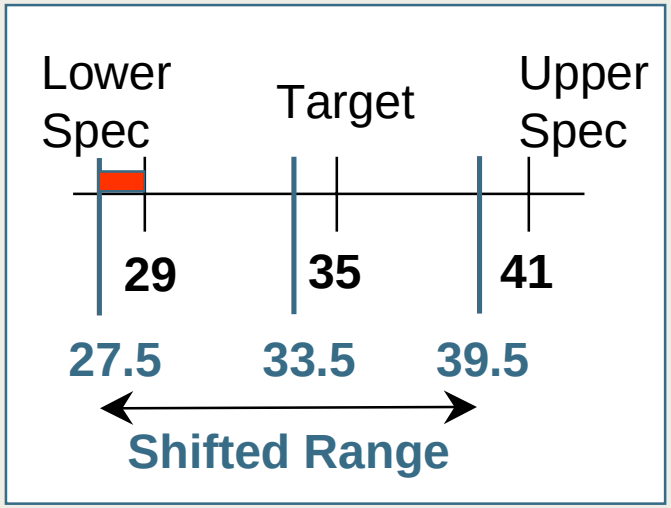
(35-29) / 1 = 6
(41-35) / 1 = 6

6 Sigma

virtually 0 outside limits

"3.4" and "Sigma" Metrics 2

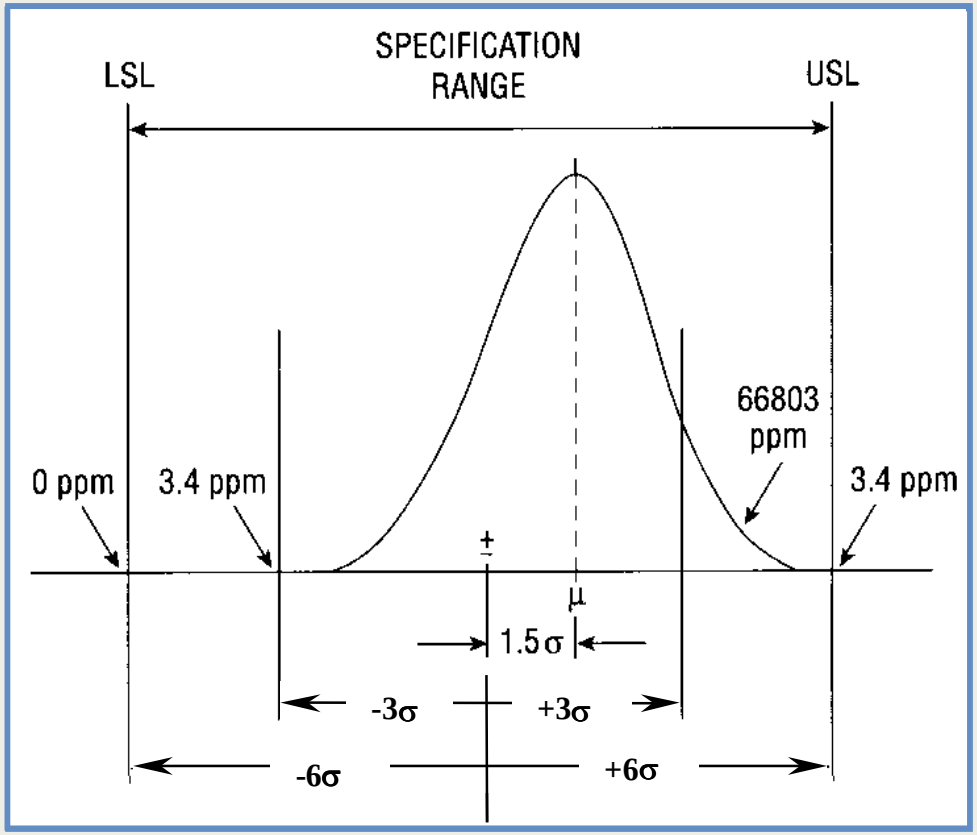
Historical data:
1.5*standard deviation shift over time



Car 2:

- Mean shifts to 33.5
- "Mean - 6*Std Dev" now extends below lower spec
- Extension corresponds to 3.4 ppm if normal distribution

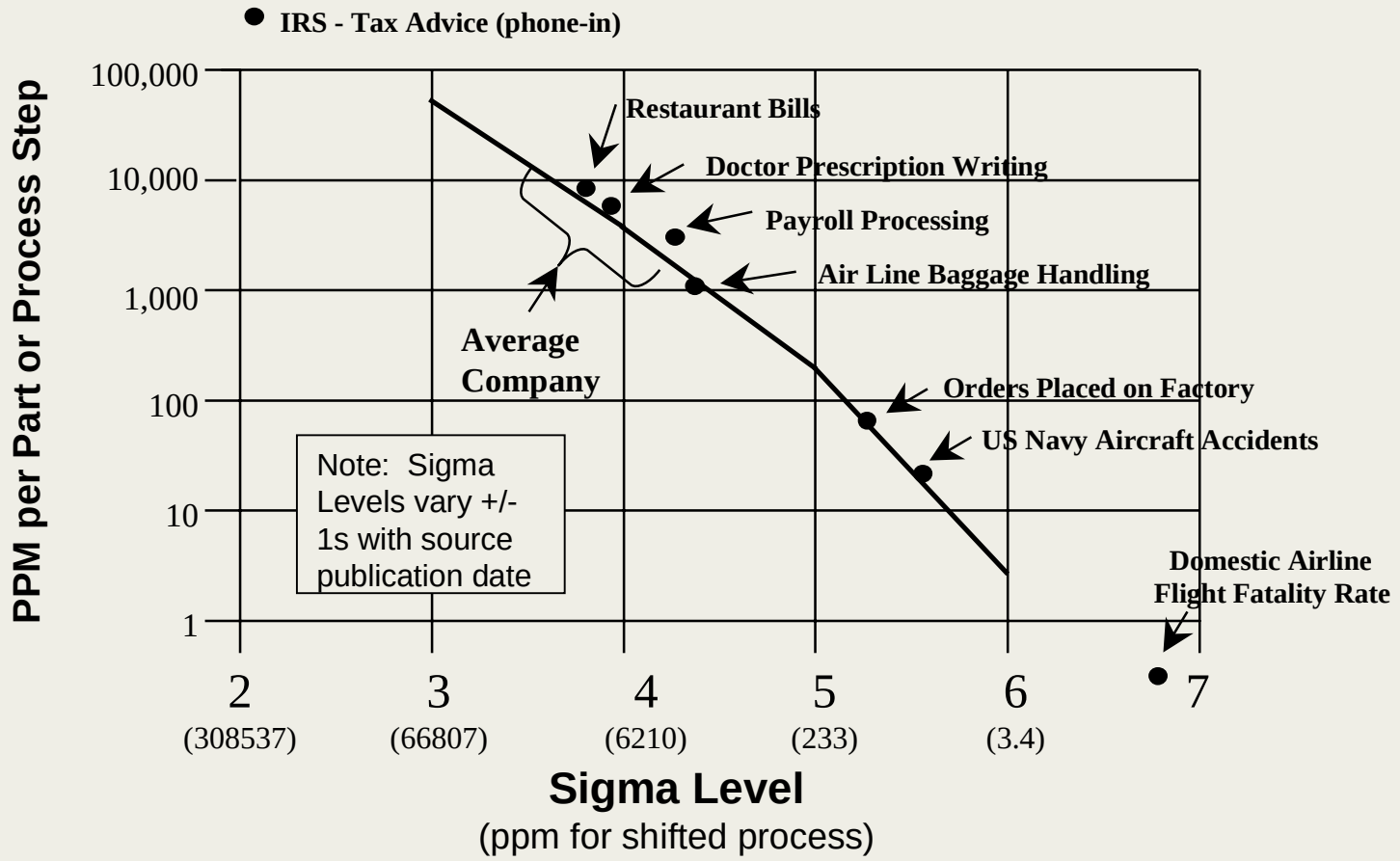
Six Sigma Process with Mean Shift



Assumptions:

- normal distribution
- process mean shift of 1.5σ from nominal is likely
- process mean and standard deviation are known
- defects are randomly distributed throughout units
- parts and process steps are independent

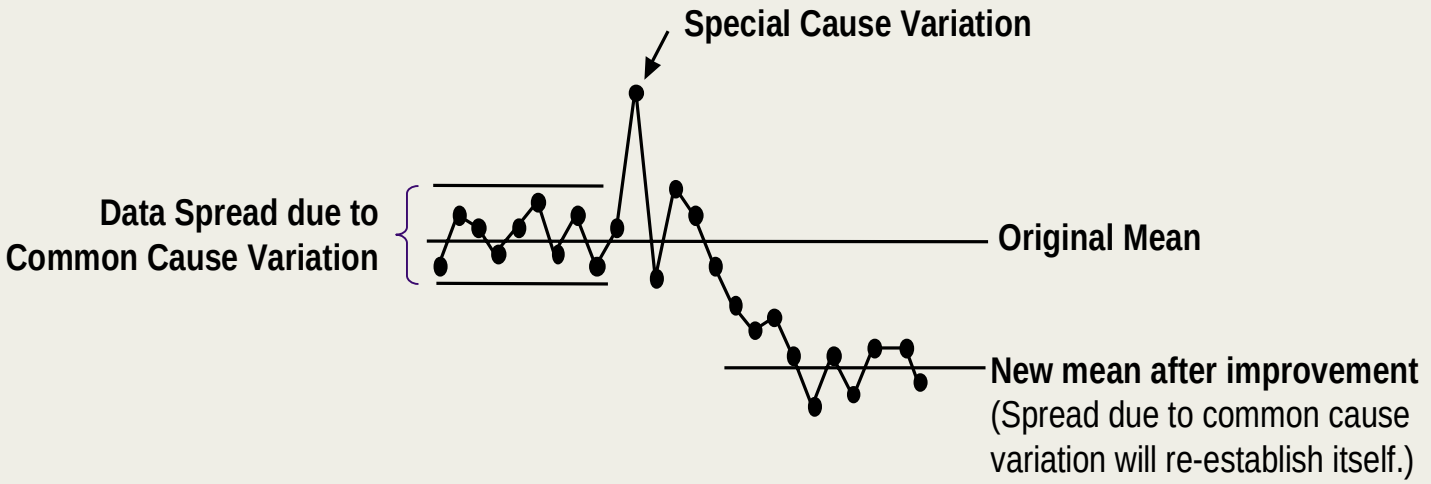
Example Sigma Levels



[Harrold 98], [Harry 00]

Statistical Thinking

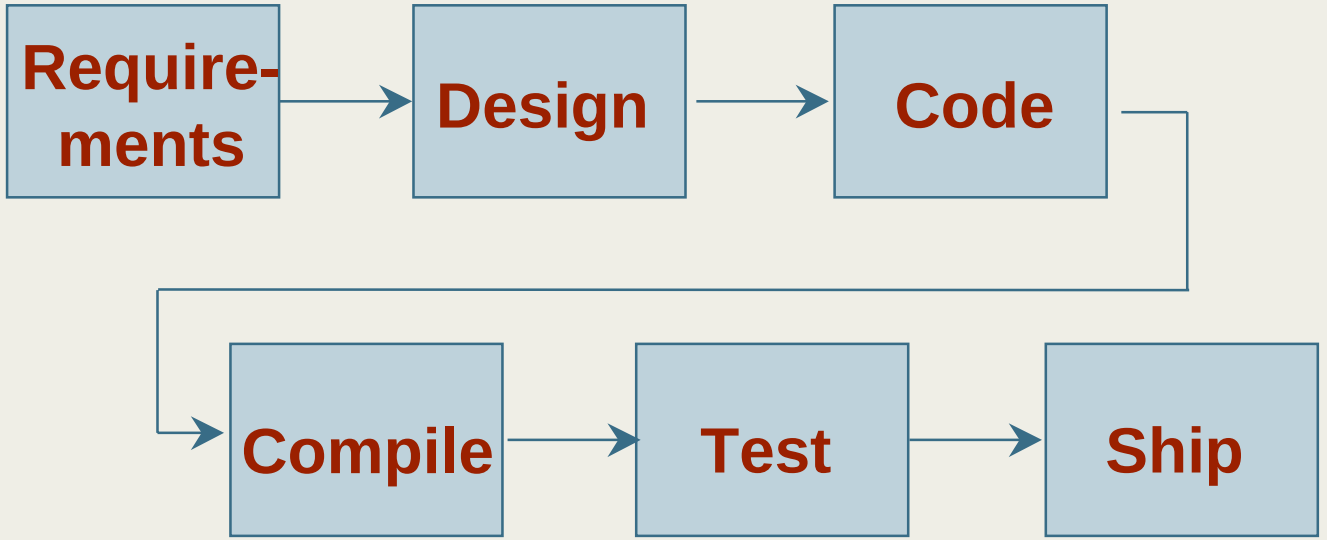
- Everything is a process
- All processes have inherent variability
- Data is used to understand variation and to drive decisions to improve the processes



[ASQ 00], [ASA 01]

Everything Is a Process

Example: Software Engineering



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Six Sigma Improvement Framework

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Six Sigma Toolkit

Define	Measure	Analyze	Improve	Control
• Benchmark • **Baseline** • Contract/Charter • Kano Model • **Voice of the Customer** • Voice of the Business • Quality Function Deployment • **Process Flow Map** • Project Management • **"Management by Fact"** **-4 What's**	• **7 Basic Tools** • Defect Metrics (i.e., "ppm") • Data Collection Forms, Plan, Logistics • Sampling Techniques	• Cause & Effect Diagrams • Failure Modes & Effects Analysis • Decision & Risk Analysis • Statistical Inference • Control Charts • Capability • Reliability Analysis • **Root Cause Analysis** **-5 Why's** • Systems Thinking	• Design of Experiments • Modeling • Tolerancing • Robust Design	Statistical Controls: • Control Charts • Time Series methods Non-Statistical Controls: • Procedural adherence • Performance Mgmt • Preventive activities

Design for Six Sigma (DFSS)

New solutions

- Rather than analysis of existing processes

Focus

- Customer and business
- Emphasis on critical-to-quality characteristics

Useful tools

- Modeling, simulation, lean, systems thinking

Applications

Six Sigma applications for Systems and Software Engineering are emerging

Survey of Applications 1

Allied Signal

- 1997 air supply control system shutdowns
- Black Belt project team commissioned to find solution

Motorola

- Inspection data analysis & unit test optimization
- Design of experiments methods & test cases
- Complexity analysis & resource allocations
- Quantitative risk management via uncertainty modeling

General Electric

- DFSS
- Six Sigma & Extreme Programming

[Harry 00], [Stoddard 00], [Kelliher 01]
Motorola & GE presentations available at http://seir.sei.cmu.edu

Survey of Applications 2

Honeywell

- PSP℠/TSP℠ & Six Sigma
  - "TSP provides the data needed to apply Six Sigma"

JP Morgan

- Capability Maturity Model® (CMM®) & Six Sigma
  - "…Six Sigma methodology is beneficial on all levels of maturity."

NCR

- CMM & Six Sigma
  - "…helps organizations working towards Level 4 & 5 deliver the best business results."

[Pavlik 00], [A-M 99], [Demery 01]
Presentations available at http://seir.sei.cmu.edu

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Initiative “Synergy”

CMM®

- Level 1-3
- Level 4-5

CMM Integration℠ (CMMI℠)

Personal Software Process℠ (PSP℠)

Team Software Process℠ (TSP℠)

®Capability Maturity Model and CMM are registered in the U.S. Patent and Trademark Office.
℠CMM Integration, CMMI, Personal Software Process, PSP, Team Software Process and TSP are service marks of Carnegie Mellon University.

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CMM and Six Sigma*

5
- Organization-wide 6σ improvements and control
- Correlation between key process areas & 6σ methods
- 6σ used within CMM efforts

Optimizing
Process improvement

4

Quantitative
Process measured and controlled

3
- Defined processes feed 6σ

Defined
Process characterized for the organization and is proactive

2
- 6σ philosophy & method focus
- 6σ "drilldown" drives local (but threaded) improvements

Repeatable
Process characterized for projects and is often reactive

1
- 6σ may drive toward and accelerate CMM solution

Initial
Process unpredictable and poorly controlled

Six Sigma is enterprise-wide.
Six Sigma focuses on "critical to quality" factors.

*Similar comments apply to CMMI

CMMI & Six Sigma*

"Within" CMMI

- Quantitative Project Management (QPM)
- Organizational Process Performance (OPP)
- Organizational Innovation and Deployment (OID)
- Measurement & Analysis (MA)
- Capability Levels
- Generic Practices

"Around" CMMI

- SEPG process improvement rollout
- Assessment methods
- Prioritization of process areas

*Similar comments apply to CMM

Illustration – "Define" 1

Business Driver

- Need 10% cost reduction in order to compete in the marketplace and stay in business

Baseline data (PSP)

- Productivity: 19 LOC/hr
- 33% of development time spent fixing defects
- Approximately 250 defects/KLOC

Illustration – "Define" 2

Goal:

- Reduce or prevent defects to reduce cost

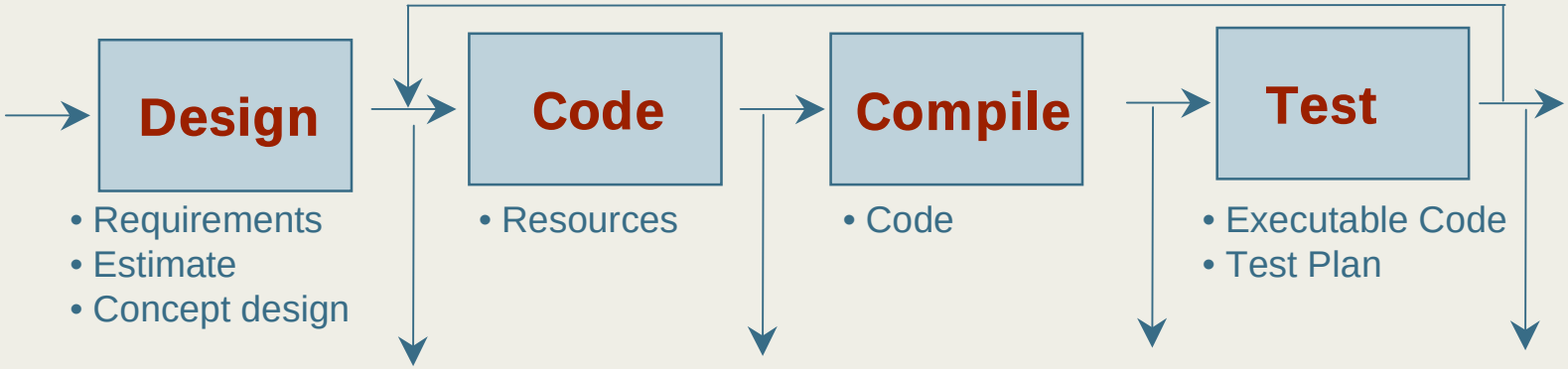
Quantitatively speaking:

- Reduce cycle time by 22 minutes/program
- Reduce fix time by 1.3 minutes/defect
- Reduce defects by 6/program
- Reduce defect density to 190 defects/LOC

… or a combination that produces 21 LOC/hr

Illustration – "Define, Measure"

PSP-based Process Map:



- **Detailed Design**
- **Test cases**
- **Data:**
  - Design Review defects
  - Fix time
  - Phase duration

- **Code**
- **Data:**
  - Defect Quantity
  - Fix time
  - Defect Injection Phase
  - Phase duration

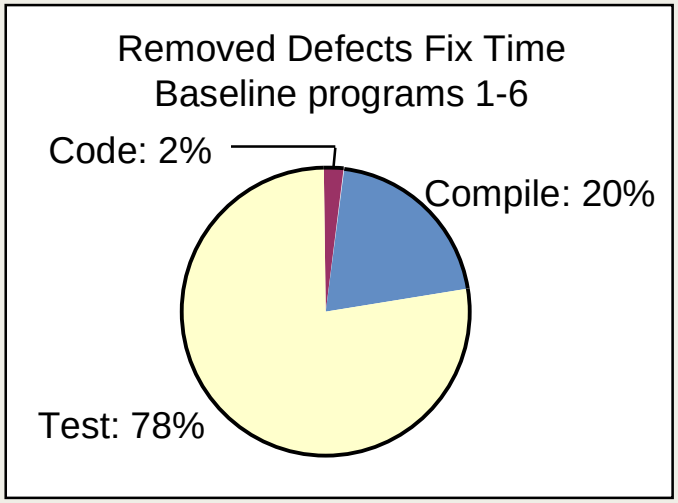
- **Executable Code**
- **Data**:
  - Defect Quantity
  - Fix time
  - Defect Injection Phase
  - Phase duration

- **Functional Code**
- **Data:**
  - Defect Quantity
  - Fix time
  - Defect Injection Phase
  - Phase duration

Illustration – "Analyze"

Opportunities to reduce repair time

- Defects removed in test: 78% of repair time
- Defects injected in design: 25% of repair time
- Defects injected in code: 56% of repair time
- Syntax defects in general: 63% of defects



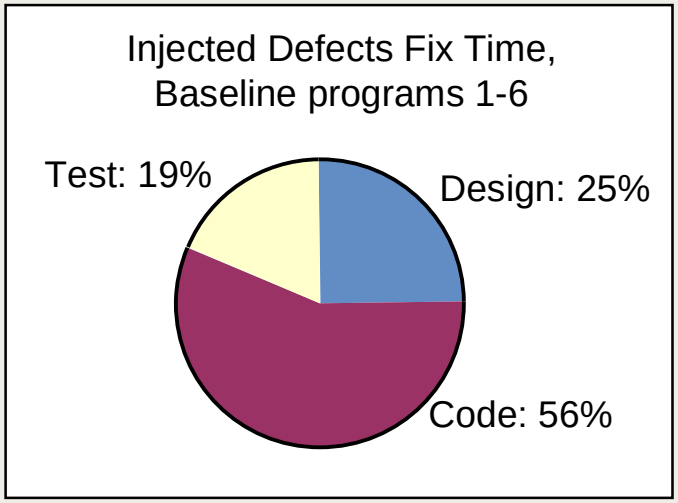
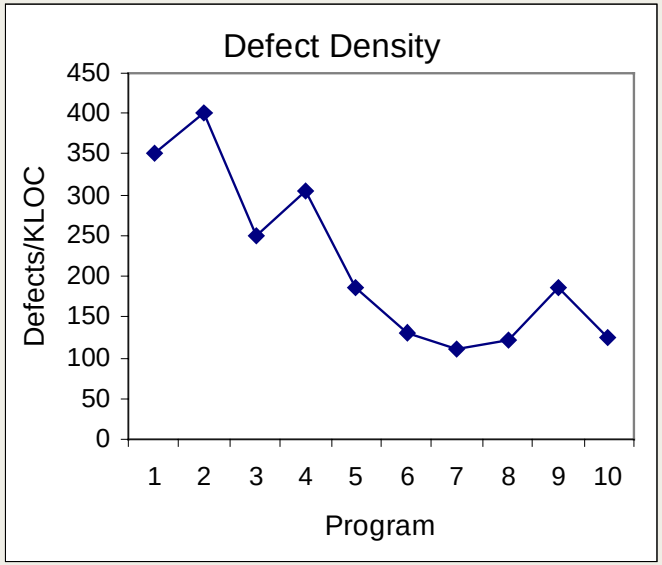


Illustration – "Improve"

Improvement Plan at Program 6

- Syntax checklist
- Well-timed reviews
- Subcategories within defect types



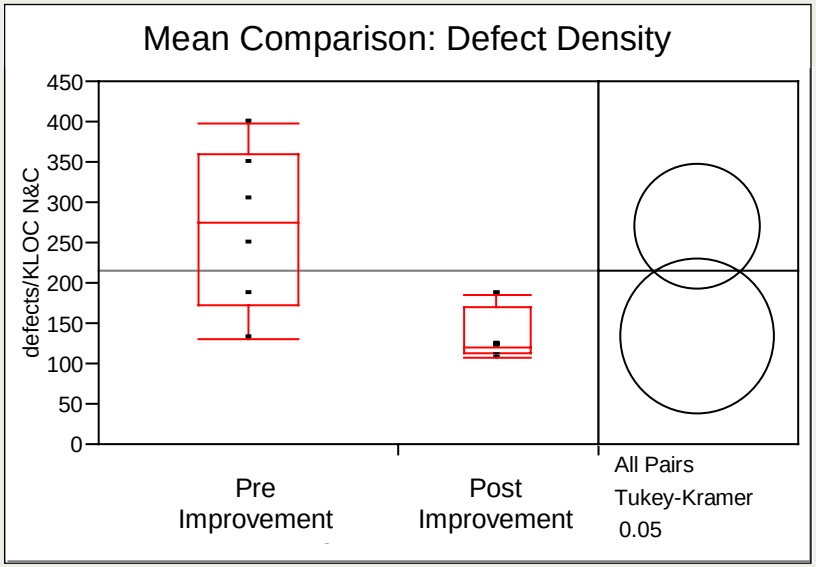
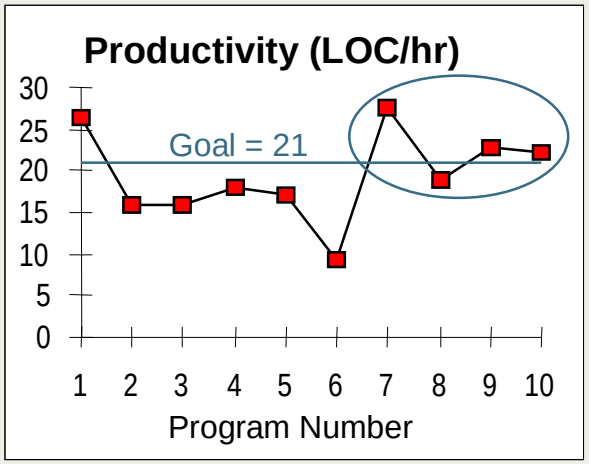


Illustration – "Control"

Tracking performance

- Quantitative goal statement
- Hypothesized root causes
- Countermeasures & contribution to impact
- Key impact indicators



Direct causes (from countermeasures):

- Fewer defects injected in code & test
- Defects removed earlier, faster (i.e., in design & code)

Root cause (need new countermeasures):

- "Re-learning" curve

Illustration – Analysis Summary

Tools used in full analysis included

- Process Mapping
- Descriptive statistics
- Means comparisons & significance testing
- Plots
  - Pie Charts
  - Trends
  - Phase profiles
  - Histograms
  - Pareto charts
  - Correlation plots
- Cause & Effect Diagrams
- “Management by Fact”

Focus was exploratory, investigative

- Ready for stability & control monitoring

Illustration – Scaling up

Illustration

- Quickly drilled down from high level cost goal to personal improvement
- Defined process in place
- Measures in place
- Continuous incremental improvements
- Event-based “step-change” improvements
- Re-learning curve
- Personal data
- Used productivity as one of impact measures

Real Life

- Drill down may be complex, may span wide breadth of organization
- May need to select or define process
- May need to develop measures
- Continuous incremental improvements
- Event-based “step-change” improvements
- Constantly changing skills, technologies
- Non-attributed data (e.g., team, project)
- Excessive productivity focus may drive unwanted behaviors

Advancing the State of 6σ & SW/SE

Repository of Examples

-http://seir.sei.cmu.edu
-concrete visualization
-relationship to models, initiatives
-variety of tools
-many views

–project, process, product

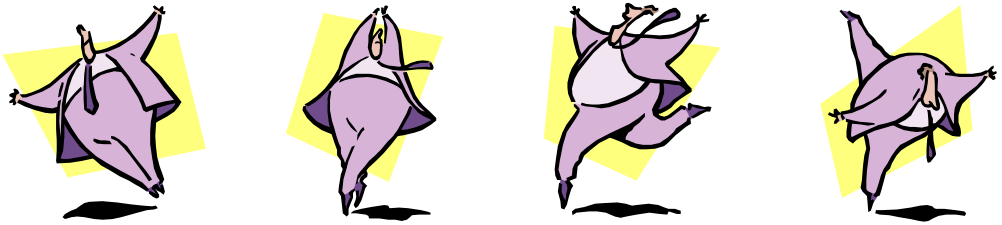
–software, systems

–maturity/capability levels

Repository of Benefits

Summary

Customer satisfaction is key driver



All efforts should link to business results

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[Pyzdek 01] Pyzdek, Thomas, *The Six Sigma Handbook*, McGraw-Hill Professional Publishing, 2001

[Stoddard 00] Stoddard, Robert W., *Implementing Six Sigma in Software*, Motorola, Inc., Software Engineering Symposium 2000, (slides available to SEIR contributors at http://seir.sei.cmu.edu)

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Additional Reading 1

Books (General Six Sigma Topics, not software-specific):

Breyfogle III, Forrest W., *Implementing Six Sigma: Smarter Solutions Using Statistical Methods*, John Wiley & Sons, 1999

Breyfogle, III, Forrest W., Cupello, James M., Meadows, Becki, *Managing Six Sigma*, John Wiley & Sons

Harry, Mikel, *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations*, Doubleday, 2000

Pyzdek, Thomas, The *Six Sigma Handbook*, McGraw-Hill Professional Publishing, 2001

Web pages & Web sites:

American Society for Quality Six Sigma Forum, http://www.sixsigmaforum.com/concepts/var/index.shtml

International Quality Federation, www.iqfnet.org (Follow the black belt links)

Six Sigma Academy, www.6-sigma.com

Software Engineering Information Repository: http://seir.sei.cmu.edu (Follow links to Measurement area then to Six Sigma)

SEI Software Technology Review: http://www.sei.cmu.edu/str/descriptions/sigma6.html

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Additional Reading 2

Journals (URL's subject to change without notice)

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