



Carnegie Mellon
Software Engineering Institute

Pittsburgh, PA 15213-3890

Six Sigma & Software/Systems Process Improvement

Jeannine M. Sivy
Software Engineering Measurement & Analysis Initiative

Sponsored by the U.S. Department of Defense
© 2002 by Carnegie Mellon University



Carnegie Mellon
Software Engineering Institute

Outline / Objectives

Six Sigma Overview

Applications Survey

Initiative Synergy

Illustration



Carnegie Mellon
Software Engineering Institute

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 ProcessSM:

- 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]

SMPersonal Software Process and PSP are service marks of Carnegie Mellon University.



Six Sigma Metrics

“3.4 ppm” – the most-cited metric

Other Measures

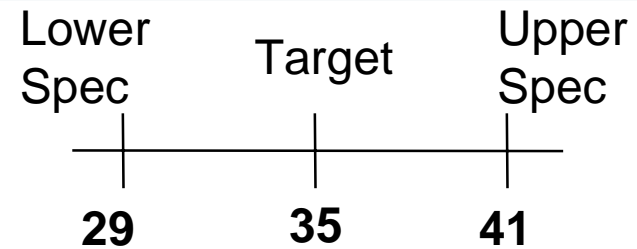
- Defect Rate, parts per million (ppm)
- Sigma Level
- Defects per Unit (dpu)
- Defects per Million Opportunities (dpmo)
- Yield



“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

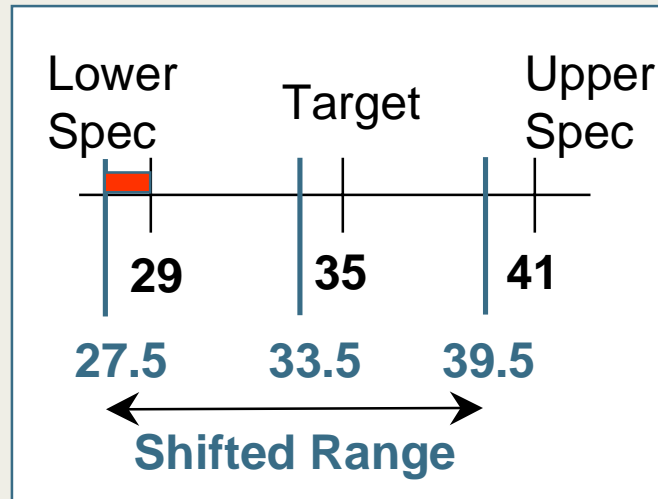
virtually 0 outside limits



“3.4” and “Sigma” Metrics ₂

Historical data:

1.5*standard deviation shift over time

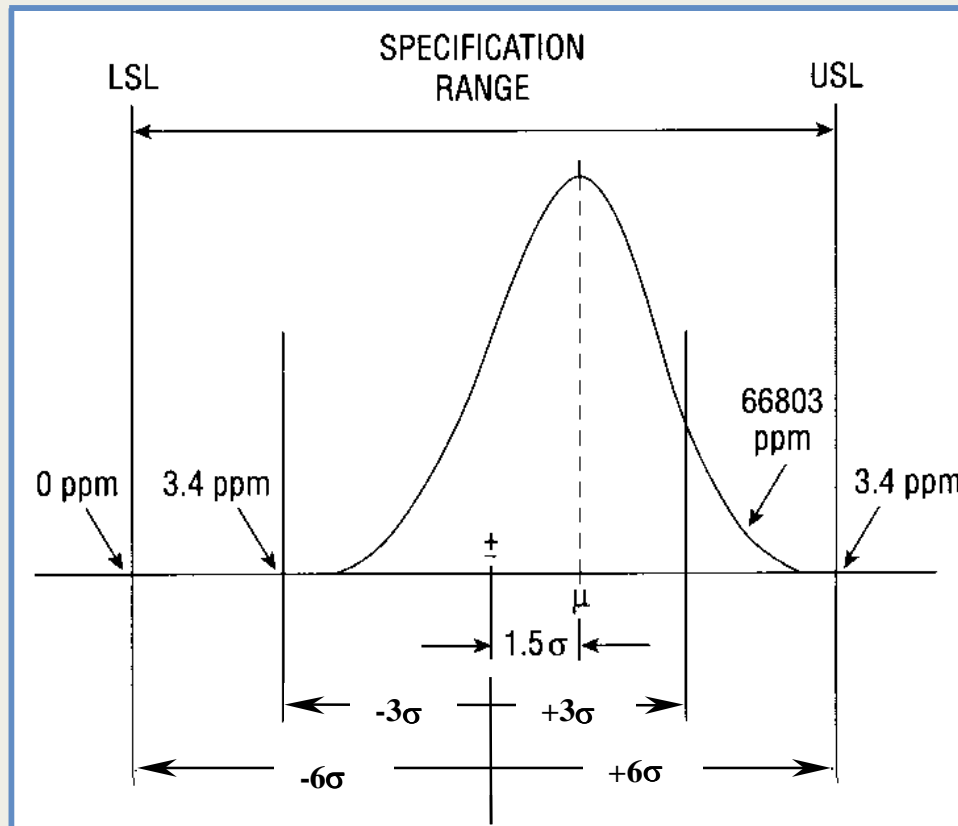


Car 2:

- 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

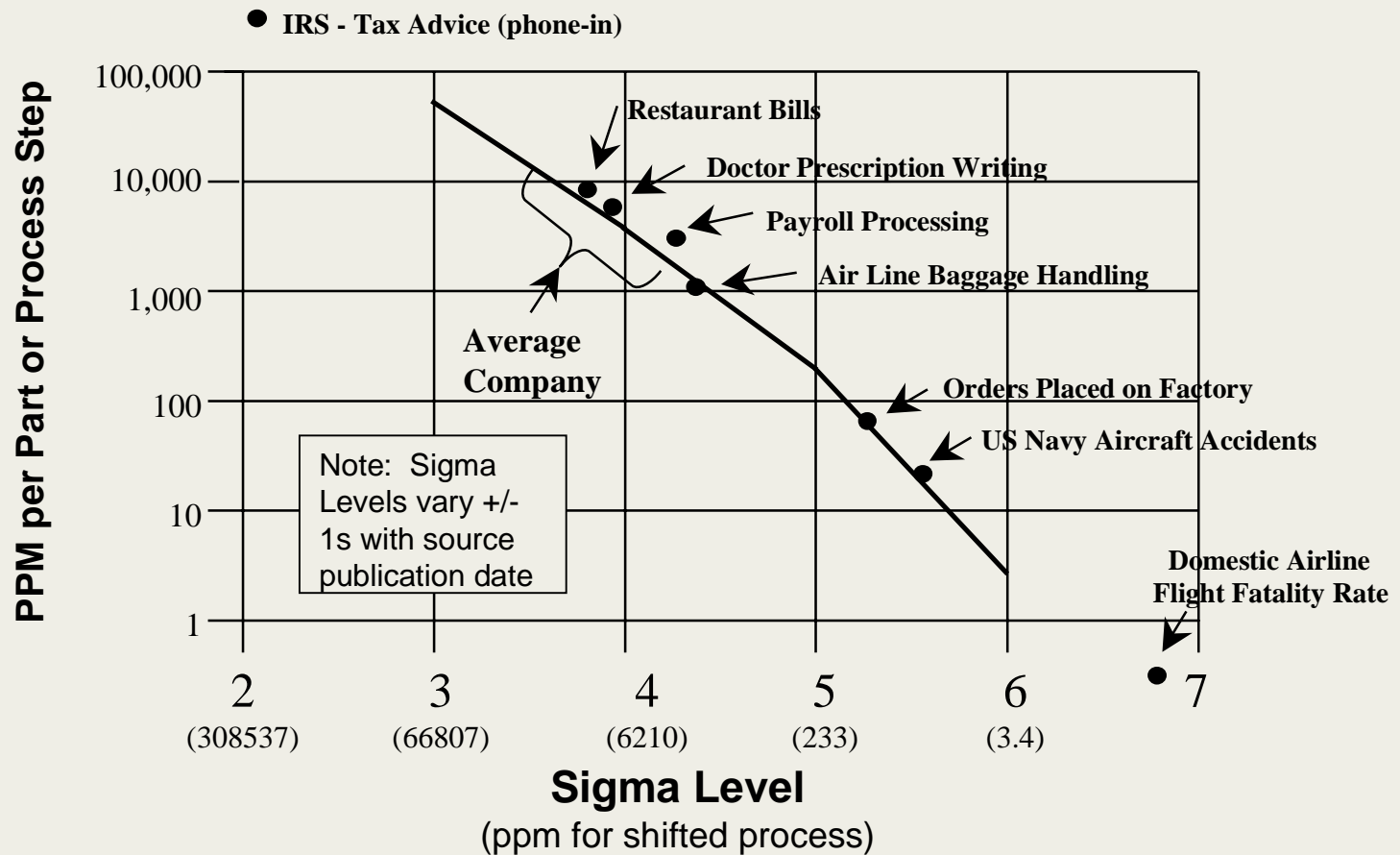


Assumptions:

- 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]

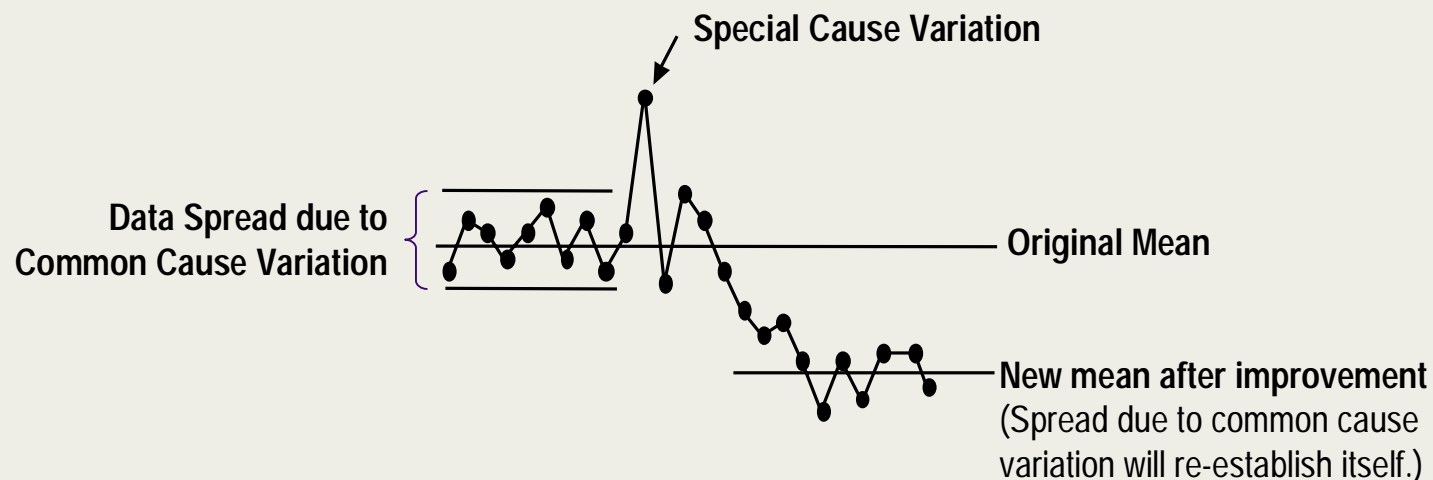
© 2002 by Carnegie Mellon University

SEPG 2002 - page 10



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

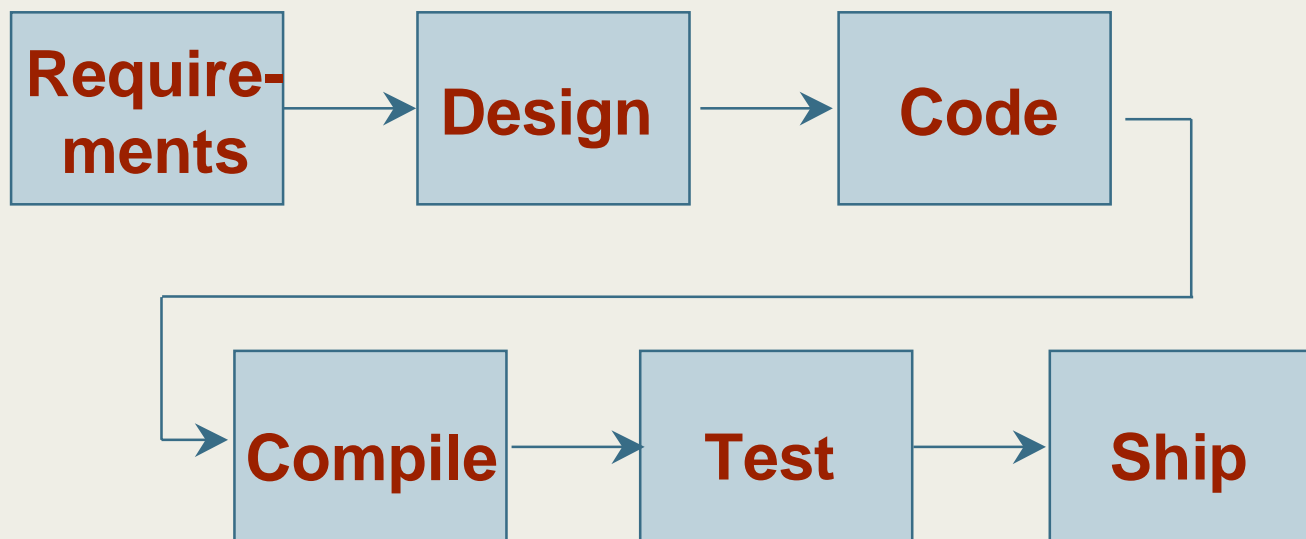


[ASQ 00], [ASA 01]



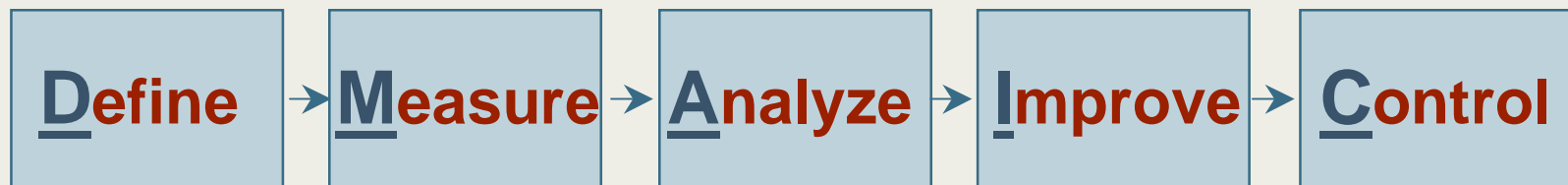
Everything Is a Process

Example: Software Engineering





Six Sigma Improvement Framework





Six Sigma Toolkit

| Define | Measure | Analyze | Improve | Control |
|---|--|---|--|--|
| <ul style="list-style-type: none">• 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 | <ul style="list-style-type: none">• 7 Basic Tools• Defect Metrics (i.e., "ppm")• Data Collection Forms, Plan, Logistics• Sampling Techniques | <ul style="list-style-type: none">• 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 | <ul style="list-style-type: none">• Design of Experiments• Modeling• Tolerancing• Robust Design | <p><u>Statistical Controls:</u></p> <ul style="list-style-type: none">• Control Charts• Time Series methods <p><u>Non-Statistical Controls:</u></p> <ul style="list-style-type: none">• 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



Carnegie Mellon
Software Engineering Institute

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

- PSPSM/TSPSM & 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.”



Carnegie Mellon
Software Engineering Institute

Initiative “Synergy”

CMM®

- Level 1-3
- Level 4-5

CMM IntegrationSM (CMMISM)

Personal Software ProcessSM (PSPSM)

Team Software ProcessSM (TSPSM)

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



CMM and Six Sigma*

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

Optimizing
Process improvement

4

Quantitative
Process measured and controlled

- 3 • Defined processes feed 6 σ

Defined
Process characterized for the organization and is proactive

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

Repeatable
Process characterized for projects and is often reactive

- 1 • 6 σ 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:

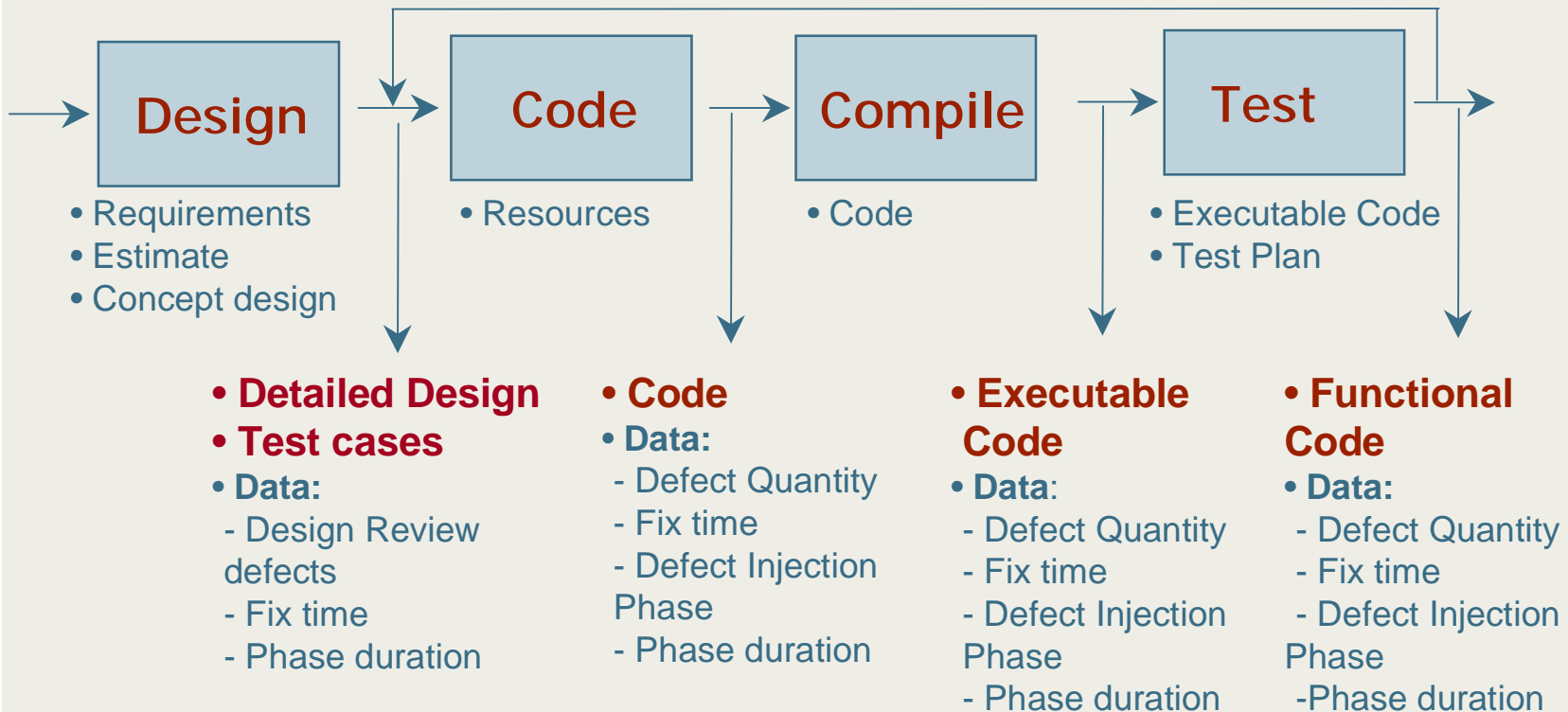




Illustration – “Analyze”

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

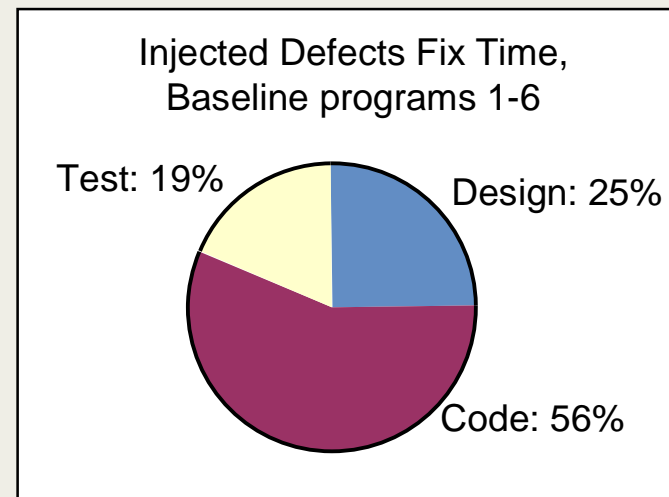
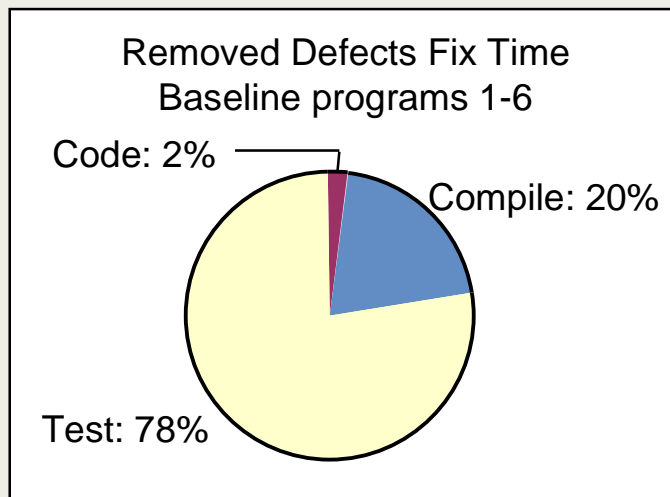




Illustration – “Improve”

Improvement Plan at Program 6

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

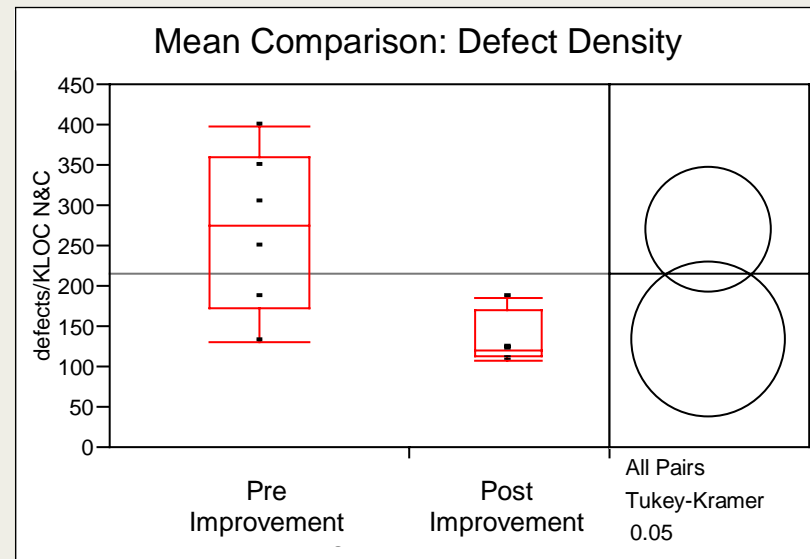
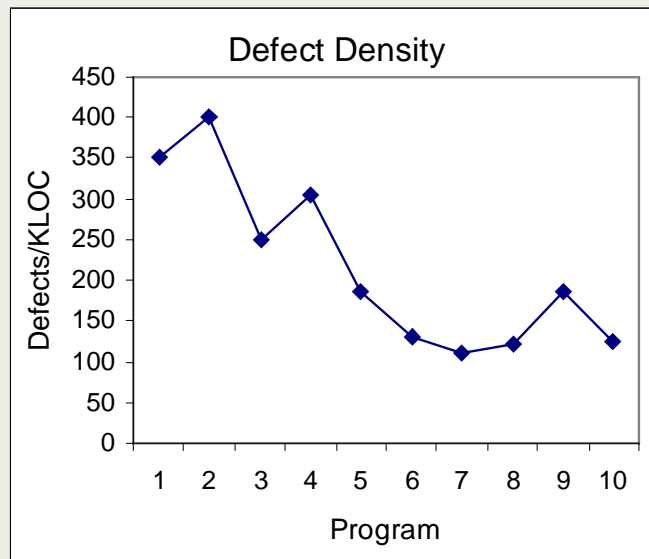
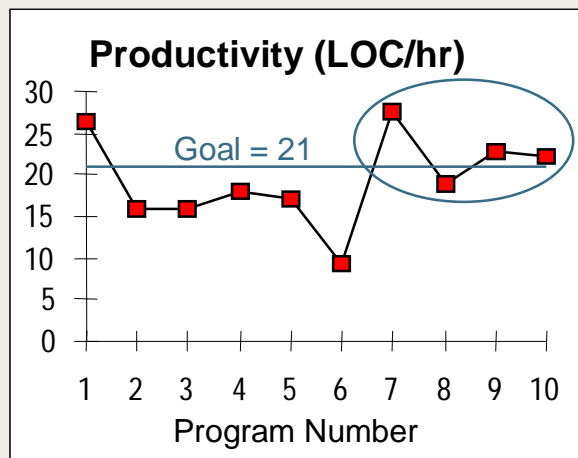




Illustration – “Control”

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 6 σ & 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

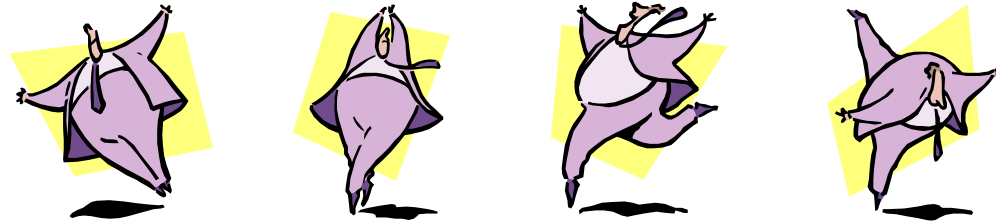


Repository of Benefits



Summary

Customer satisfaction is key driver



**All efforts should link
to business results**



Carnegie Mellon
Software Engineering Institute

Contact Information

Jeannine Sivy
Software Engineering Institute
Measurement & Analysis Initiative
jmsivy@sei.cmu.edu
412-268-7994



References 1

- [A-M 99] Abdel-Malek, Nabil and Anthony Hutchings, *Applying Six Sigma Methodology to CMM for Performance Improvement*, JP Morgan, European SEPG 1999, (slides available to SEIR contributors at <http://seir.sei.cmu.edu>)
- [ASA 01] American Statistical Association, Quality & Productivity Section, *Enabling Broad Application of Statistical Thinking*, <http://web.utk.edu/~asaqp/thinking.html>, 2001
- [ASQ 00] ASQ Statistics Division, *Improving Performance Through Statistical Thinking*, Milwaukee: ASQ Quality Press, 2000. H1060
- [Arnold 99] Arnold, Paul V., *Pursuing the Holy Grail*, MRO Today, June/July 1999, www.progressivedistributor.com/mro/archives/editorials/editJJ1999.html
- [Breyfogle 99] Breyfogle III, Forrest W., *Implementing Six Sigma: Smarter Solutions Using Statistical Methods*, John Wiley & Sons, 1999
- [Bylinsky 98] Bylinsky, Gene, *How to Bring Out Better Products Faster*, Fortune, 23 November 1998
- [Demery 01] Demery, Chris and Michael Sturgeon, *Six Sigma and CMM Implementation at a Global Corporation*, NCR, SEPG 2001, (slides available to SEIR contributors at <http://seir.sei.cmu.edu>)
- [Harrold 99] Harrold, Dave, *Designing for Six Sigma Capability*, Control Engineering Online, January 1999, <http://www.controleng.com/archives/1999/ctl0101.99/01a103.htm>



References 2

- [Harry 00] Harry, Mikel, *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations*, Doubleday, 2000
- [Kelliher 00] Kelliher, Timothy P., Daniel J. Blezek, William E. Lorensen, James V. Miller, *Six Sigma Meets Extreme Programming*, General Electric Corporate R&D, (paper available to SEIR contributors at <http://seir.sei.cmu.edu>)
- [Pavlik 00] Pavlik, Rich, Cary Riall and Steve Janiszewski, *Deploying PSPSM, TSPSM, and Six Sigma Plus at Honeywell*, Honeywell Air Transport, SEPG 2000, (slides available to SEIR contributors at <http://seir.sei.cmu.edu>)
- [Purcell 00] Purcell, Leitha, *Experiences Using Six Sigma in a SW-CMM[®] Based Process Improvement Program*, Northrop Grumman, SEPG 2000, (slides available to SEIR contributors at <http://seir.sei.cmu.edu>)
- [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>)



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.igfnet.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>



Additional Reading ₂

Journals (URL's subject to change without notice)

6 Sigma Pro, Quality Digest, May 2000, <http://www.qualitydigest.com/may00/html/sixsigmapro.html>

6 Sigma Con, Quality Digest, May 2000, <http://www.qualitydigest.com/may00/html/sixsigmacon.html>

Arnold, Paul V., *Pursuing the Holy Grail*, MRO Today, June/July 1999,
<http://www.mrotoday.com/mro/archives/Editorials/editJJ1999.htm>

Card, David, *Sorting out Six Sigma and the CMM*, IEEE Software, May/June 2000

Dusharme, Dirk, *Six Sigma Survey: Breaking Through the Six Sigma Hype*, Quality Digest, November 2001, <http://www.qualitydigest.com/nov01/html/sixsigmaarticle.html>

Paul, Lauren Gibbons, "Practice Makes Perfect," CIO Enterprise Magazine, 15 January 1999,
http://www.cio.com/archive/enterprise/011599_process.html

Harrold, Dave, *Designing for Six Sigma Capability*, Control Engineering Online, January 1999,
<http://www.controleng.com/archives/1999/ctl0101.99/01a103.html>

Harrold, Dave, *Optimize Existing Processes to Achieve Six Sigma Capability*, Control Engineering Online, March 1999, <http://www.controleng.com/archives/1999/ctl0301.99/03a301.html>

Lahiri, Jaideep, *The Enigma of Six Sigma*, The Net Business of the India Today Group,
<http://www.india-today.com/btoday/19990922/cover.html>

Pyzdek, Thomas, *Why Six Sigma is Not TQM*, Quality Digest, February 2001,
<http://www.qualitydigest.com/feb01/html/sixsigma.html>

Pyzdek, Thomas, *Ignore Six Sigma at Your Peril*, Quality Digest, April 2001,
<http://www.qualitydigest.com/april01/html/sixsigma.html>