A Practical Application of CMMI Level 5 Practices

A Case Study of the Future Scout and Cavalry System (FSCS) Program
circa 2001

ASEE Workshop on Software Engineering Process Improvement - 08 February 2003

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Topics

- FSCS Program and Problem Overview
- Raytheon’s Foundation for Process Improvement
- Achieving Continuous Improvement on FSCS
Act One

FSCS Program and Problem Overview
FSCS Program Overview

- Future Scout and Cavalry System (FSCS)
  - 42 month ATD program (January ’99 - July ’02)
  - US / UK joint program

- Advanced Long Range Reconnaissance Mission

- C130 Transportable

- FSCS Represents State of the Art in Architectures for Combat Vehicles
  - Systems and software architecture
  - Computing resources and electronics
FSCS Program Overview - SIL I&T

Sensor Data Management

SIL I&T emphasizes internal messages and processing

Crew Station Test Driver

Segment Manager

BIT Manager

ESS Controller

VMSS Controller

FLIR Controller

LOS Controller

Laser Controller

INS Controller

Radar Controller

Boresight Controller

VLOS Controller

VFLIR Controller

Elevated Sensor Suite Emulator

Vehicle Mounted Sensor Suite Emulator
Sensor Data Management

System I&T emphasizes external interfaces ...

FLIR Controller
LAS Controller
EState
VLOS

Crew Station
System Mode Manager
BI T Manager
ESS Controller
VFLIR Controller

FLIR
Shape
EState
VLOS

VFLIR Controller

CITV

Raytheon
Network Centric Systems
During **System I&T**, the Test team complained about defects that had escaped from **SIL I&T**

- Defects were in message sequences and software component inter-relationships (i.e. behaviors)
- Defects were not in message formats (i.e. ICDs)

**Defect Containment thresholds were exceeded for System I&T**

- Thresholds were defined in the Quantitative Project Management (QPM) Plan
- Discovered during the September 2001 Metrics Analysis meeting

The FSCS QPM Plan includes metrics goals, thresholds, and process for collection and analysis
FSCS Program Overview – The Problem

### Stage Originated

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**Goal**

- Detected In Stage: 348, 77% Detected In Stage: >80%
- Total Escaped: 105, 23% Total Escaped: <20%

Analysis of Build 1 defect containment metrics revealed 57 out of stage implementation defects detected during System I&T

QPM Thresholds

Exceeded!
Act Two

Raytheon’s Foundation for Process Improvement
Process Improvement Roadmap

Set Objective Performance and Quality Goals (CMM 4)

Establish Process Capability Baseline (CMM 4)

Causal Analysis and Resolution (CMM 5)

Select And Prioritize Improvements (CMMI 5)

Deploy Improvements (CMMI 5)

Pilot Improvements (CMMI 5)

Measure Improvements and Rebaseline (CMMI 5)

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Quantitative Process Management Key Process Area

- “The purpose of Quantitative Process Management is to control the process performance of the software project quantitatively.” - CMM V 1.1
- FSCS used a Quantitative Process Management (QPM) Plan to measure and monitor the software process
- The Defect Containment Metric was Analyzed and Compared to the Organization’s Expected Range Of Values based on the QPM Plan
Organizational Innovation and Deployment

“The purpose of Organizational Innovation and Deployment is to select and deploy incremental and innovative improvements that measurably improve the organization’s processes and technologies” - CMMI SE/SW v 1.1

FSCS piloted selected improvements on subsequent builds and deployed piloted improvements on subsequent builds of other Software Configuration Items (SCIs)

Causal Analysis and Resolution

“The purpose of Causal Analysis and Resolution is to identify causes of defects and other problems and take action to prevent them from occurring in the future” - CMMI SE/SW v 1.1

FSCS performed causal analysis as part of monthly metrics analysis activities and identified resolutions as improvement action plans
Raytheon Six Sigma Foundation

Process Improvement Roadmap

- Measure Improvements and Retracting (CMMI 5)
- Deploy Improvements (CMMI 5)
- Pilot Improvements (CMMI 5)
- Select and Prioritize Improvements (CMMI 5)
- Causal Analysis and Resolution (CMMI 5)
- Establish Process Capability Baseline (CMMI 4)
- Set Objective Performance and Quality Goals (CMMI 4)

Visualize

Achieve

Commit

Prioritize

Improve

Characterize

Raytheon Six Sigma was used to Achieve Continuous Improvement
R6¢ Maps to CMMI Level 5

1. Set Objective Performance & Quality Goals
2. Measure Improvements & Re-baseline
3. Establish Process Capability Baseline
4. Select & Prioritize Improvements
5. Pilot Improvements
6. Deploy Improvements
7. Commit
8. Prioritize

Process Capability for CPI
Cp = 0.09
Cpk = -0.08
Cpk (upper) =
Cpk (lower) =
Cr = 10.96
Cpm = 0.09
K = -1.14
Act Three

Achieving Continuous Improvement on FSCS
The FSCS Metrics Analysis process included detailed analysis of the defect metrics to determine root cause.

- Process
  - Requirements instability
  - Design instability
  - Drive to improve SPI

- Hardware
  - Actual hardware not available for testing
  - SIL emphasis on I&T with emulators

- People
  - SIL testing experience
  - Unit testing knowledge/experience

- Software
  - Emulator design not based on actual hardware

- Software
  - Defects escaping implementation and software integration stages

Performed root cause analysis on defects escaping into System I&T.
Causal Analysis

- Emulator design was based on ADDs, design artifacts, and TEMs instead of actual hardware
  - Due to intentionally late arrival of re-used HW
  - Inherent flaw since checks and balances that enable requirement verification was missing

- During SIL I&T too much time was spent debugging the emulators instead of debugging deliverable code
  - Any time at all was too much time

- During System I&T, the regression test turned into a comprehensive re-test
  - Intent to prove the software had not changed since SIL I&T expanded into a re-verification of requirements because the actual HW was different than the emulators
Causal Analysis and Resolution

- De-emphasize integration with emulators
  - Whenever possible, use real software and hardware

- Re-engineered the process for Unit Test in the Implementation stage and ...
  - Prepared and presented a Unit Test JITT

... Testing in the SIL I&T stage
  - Integrate real software and hardware, hold off on Test

- Emphasize early testing of final system configuration
  - Assign a SIL I&T lead to coordinate activities
  - Focus on external interfaces
    > Includes most technical unknowns and competition for scarce hardware resources
  - Start the System I&T stage as soon as possible (but no sooner)
Quantitative Process Management (CMM L4) +

Causal Analysis and Resolution (CMMI L5) +

Organizational Innovation and Deployment (CMMI L5) +

Raytheon Six Sigma Process =

Measurable Continuous Process Improvement
Comparison of B1 and B2/3/4 Metrics

- **Productivity**
  - B1 SIL I&T Productivity = 2.1 LOC/Hr
  - B2/3/4 SIL I&T Productivity = 3.4 LOC/Hr
  - 62% improvement

  Other Factors: Team had gained experience in all aspects of development

- **CPI and SPI**
  - JUL 2001 Cum CPI / SPI = .91 / .93
  - JAN 2002 Cum CPI / SPI = .96 / .99
  - 5% / 6% improvement

  Other Factors: By July 2001, 81% of budget was spent making it difficult to improve the cumulative CPI and SPI
Comparison of B1 and B2/3/4 Metrics

Comparison of B1 and B2/3/4 SIL I&T Labor Hours

- 26,361 ELOC
- 39,798 ELOC
- 16% fewer hours were used to integrate 51% more ELOC (including regression test)

3462
2901

B1
B2/3/4
## Comparison of B1 and B2/3/4 Metrics

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Goal:
- Detected In Stage: 348 (77%)
- Total Escaped: 105 (23%)

### Tracer Build 2 Defect Containment

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Goal:
- Detected In Stage: 438 (81%)
- Total Escaped: 104 (19%)

More defects were identified in-stage during B2 Implementation = 132% improvement

26,361 ELOC

19,869 ELOC

In Range!
### Comparison of B1 and B2/3/4 Metrics

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Fewer out of stage Implementation defects were detected in B2 System I&T than in B1 System I&T = 39% improvement

19,869 ELOC

In Range!
Results

- During SIL I&T, too much time was spent debugging the emulators instead of debugging deliverable code
  - Mitigated: SIL I&T productivity improved in B2/3/4
  - Mitigated: CPI / SPI improved in B2/3/4

- During System I&T, the regression test turned into a comprehensive re-test
  - Mitigated: Fewer labor hours were spent integrating more code in B2/3/4 SIL I&T

- During System I&T, ESIL team complained about high number of defects that had escaped from SIL I&T
  - Mitigated: In stage defect detection increased 132% (Implementation stage), out of stage defect detection decreased 39%
Conclusions

- **Metrics and Analysis are essential to continuous process improvement**
  - Metrics are key to triggering and measuring process changes

- **Develop a strong QPM Plan including metrics collection from the beginning**
  - It is unknown at the beginning which metrics will eventually become the most valuable
  - You can never go back and collect what you missed

- **QPM and metrics are valuable for convincing customers and management to support process improvements**
Backup
Normalized LOC Calculations

- **In Stage Defects**

\[
\frac{117 - \frac{204}{1 - \frac{26,361-19,869}{26,361}}}{117} = 132\%
\]

- **Out of Stage Defects**

\[
\frac{57 - \frac{26}{1 - \frac{26,361-19,869}{26,361}}}{57} = 39\%
\]
Comparison of B1 and B2/3/4 Metrics

Comparison of B1 and B2 SIL I&T Labor Hours

- 26,361 ELOC
- 19,869 ELOC

-41% fewer hours were used to integrate a 25% less ELOC (including regression test)
CMMI Level 5 Behavior Context Diagram

1. Know organizational competencies, needs, & goals
2. Move process capability towards org. goals
3. Determine program root causes for defects
4. Determine organization root causes for defects
5. Identify and prioritize improvement opportunities
6. Experiment with improvement opportunities
7. Institutionalize validated improvements
8. Monitor improvement of organizational capability

Improvement Suggestions