Transition from SW-CMM® to CMMI®: The Benefits Continue!

CMMI® Technology Conference 2003
November 19, 2003

Joan Weszka
Lockheed Martin Mission Systems
Systems & Software Resource Center

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Agenda

- Context
- Background on Lockheed Martin’s (LM) CMMI® transition approach
- Benefits in the Software CMM® and CMMI® eras
  - LM Systems Integration (Owego, NY)
  - LM Maritime Systems & Sensors – Radar Systems (Syracuse, NY)
  - LM Maritime Systems & Sensors – Undersea Systems (Manassas, VA)
Context

- A number of Lockheed Martin organizations that tracked quantitative process improvement benefits during their SW-CMM® high maturity journey have now transitioned to CMMI®
- Experience to date indicates that these benefits have continued with CMMI® implementation
- Benefits derived are not attributable *only* to CMMI®
  - Many initiatives are underway concurrently with CMMI® (and SW-CMM®) deployment
Lockheed Martin’s CMMI® Deployment

Approach

- Many Lockheed Martin (LM) companies have institutionalized best-of-breed integrated processes (e.g., IPPD)
- Multiple process models and standards are in use
- LM identified industry and internal best practices as sources for corporate-wide process requirements
- The LM Integrated Engineering Process (LM-IEP) standard synthesizes these requirements

*Lockheed Martin’s Integrated Engineering Process Standard is being deployed under corporate policy.*
Key Tenets of Lockheed Martin’s CMMI® Transition

● Address CMMI® in the context of your organization’s business requirements
  ≫ Lockheed Martin’s Integrated Engineering Process (LM-IEP) standard includes CMMI®, in addition to other standards and requirements (e.g., ISO/IEC 15288, ISO 9001:2000)

● Adopt an incremental appraisal approach
  ≫ Lockheed Martin Continuous Appraisal Method (CAM) has been successfully deployed with CMMI® and is being extended for use with LM-IEP
LM-IEP, CAM and CMMI® Relationship

- CMMI® provides a set of integrated process and appraisal method requirements

* Appraisal Requirements for CMMI® (ARC)

CAM is an ARC Class A appraisal method.
LM-IEP Context Diagram

LM CPSs

ANSI/EIA-632
ISO 9001:2000
CMMI® V1.1
ISO/IEC-12207
LM Hardware Process Standard
ISO/IEC-15288
IEEE 1220

Industry Stds
Government Stds

Domain Specific Standards

LM-IEP Standard
EPI Process & Methods

Organizational Standard Process

Project Defined Process

Integrated Processes
Integrated Methods
Integrated Work Products

Company or Business Unit

cps – corporate policy statement
EPI – engineering process improvement

In LM-IEP V1.3 issued 4/02
In LM-IEP V2.0 issued 1/03
Reference only
Informative only

Common Source Standards

Industry Stds
Government Stds

Project Specific Standards

Tailored OSP
Continuous Appraisal Method (CAM) – Design Goals

- Minimize appraisal preparation and reduce cost
- Integrate process improvement with process appraisal activities
- Facilitate appraisal scheduling and minimize disruption for participants
- Provide an appraisal environment conducive to process improvement
- Promote institutionalization

CAM is being used with CMMI® and being extended for appraisal of LM-IEP requirements.
Overview of Incremental Appraisal Using CAM

Institutionalization focus with minimal project disruption
Feedback on CAM usage

- CAM has been or is being deployed at 12 Lockheed Martin operating units using CMMI®
  - 6 prior CAMs have been completed using EIA/IS 731
- Experience with CAM has been positive:
  - More focus on process improvement
  - Less invasive to programs
  - Less stressful to the organization
  - More value-add, in-depth findings
  - More cost effective
Lockheed Martin Systems Integration

% Improvement in Software Defects per Million Delivered Source Lines of Code

Improvements Since 1992
12.4 % Average per Year
80.5% Overall

Contributors
- Inspection Discipline & Effectiveness
- Defect Prevention Process
- Process Maturity & Compliance
- Tool Usage (Automated Checking Tools)
- Increased amount of reuse

NOTE: Post Delivery Defects Are Defined As Defects That Are Tracked for 2 Years After Customer Delivery
Lockheed Martin Systems Integration – Owego Software Productivity

Software Productivity (All Software including Reuse)

**Improvements Since 1992:**
9.8% Average per Year

**Contributors:**
- Increased Reuse (Domain Specific)
- Process Maturity and Compliance
- Process Consistency
- Increased use of High Order Language / 4th Generation / Object Oriented
- Use of development and test tools
LM Maritime Systems & Sensors Tactical Systems
Process Improvement Credentials

- Oct. 1999 – Attained SW-CMM® level 4
- Dec. 2000 – Attained Systems Engineering Capability Model (EIA 731) level 3
- Jan. 2001
  - Began focus on integrated process improvement
  - Began transition to CMMI®
- June 2002 – May 2003 CAM Appraisal
  - OSP: Target profile 5 for CMMI®-SE/SW/IPPD/SS
  - Projects: Target profile 3 for CMMI®-SE/SW
- August 2003 – SCAMPI℠ Appraisal
  - Achieved target profile 3 for CMMI®-SE/SW

® SW-CMM is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University.
LM Maritime Systems & Sensors Tactical Systems
Initiatives

- Streamlining of references and guidance documents which supplement the OSP
- Value stream mapping of engineering process/business model
- LM-IEP gap analysis
- Self audit process compliance
- Airworthiness manual
- Risk Management methodology best practice
- Upgrade of Process Asset Library (PAL)
- Mechanical engineering guidebook
- Change management pilot
- Defect prevention pilot
LM Maritime Systems & Sensors Tactical Systems
Software Productivity

Source Statements per Hour vs. Year

Level 3 CMM®
Level 4 CMM®
Level 3 CMMI®
LM Maritime Systems & Sensors Radar Systems
Process Improvement Credentials

- SW-CMM® level 5 (CBA IPI\textsuperscript{SM}) in Dec. 1999
- Systems Engineering Capability Model (EIA/IS 731) level 3+ (CAM) in Dec. 1999
- Focus on integrated process improvement including hardware began in 2000
- Transition to CMMI\textsuperscript{®} began in 2000
- CMMI\textsuperscript{®}-SE/SW/IPPD target profile 4 (CAM) in Nov. 2002

\textsuperscript{®} SW-CMM and CMMI are registered in the U.S. Patent and Trademark Office by Carnegie Mellon University.
Functional Excellence Objectives - 2003

- LM 21 business excellence
- Enhance program performance
- Improve productivity
- Continue to manage the business with quantitative data
- Improve quality of the product and process
- Provide a supportive infrastructure for process improvement
- Demonstrate continued process maturity leadership
- Manage technology innovations to support program performance
- Document processes and procedures core to our success
- Develop and train employees for current and future assignments
Software Productivity and Quality Performance Application of Best Practices and Investment Has Resulted in Significant Improvements in Quality and Cost. As error rates declined, productivity increased by 80+%. 

Lockheed Martin: NE&SS-Syracuse - Software Productivity & Quality Performance History
LM Maritime Systems & Sensors – Undersea Systems
Process Credentials

- **Systems & Software Engineering***
  - Software CMM® Level 4 (CBA IPISM) - June 1995
  - Software CMM® Level 5 (CBA IPISM) - February 1999
  - CMMI® & EIA-731 Level 3 (CAM) - October 2001
  - CMMI® Level 5 (CAM) - October 2002

- **Quality Management**
  - AS9000 - November 1997
  - Defense Contract Management Agency (DCMA) ISO 9001 Qualified - December 1997
  - AS9100A – December 2002

*Assessed programs comprise over 80% of the Undersea Systems development programs, and all parts of the development cycle.*

*SM CBA IPI is a service mark of Carnegie Mellon University*
## LM Maritime Systems & Sensors – Undersea Systems

### Process Chronology

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1970s</strong></td>
<td>Top-down Structured Programming</td>
</tr>
<tr>
<td></td>
<td>Design &amp; Code Inspections</td>
</tr>
<tr>
<td></td>
<td>1980-2</td>
</tr>
<tr>
<td></td>
<td>Functional Decomposition</td>
</tr>
<tr>
<td></td>
<td>SW Engineering Workshop</td>
</tr>
<tr>
<td></td>
<td>Advanced Design Workshop</td>
</tr>
<tr>
<td><strong>1983</strong></td>
<td>SW Management Workshop</td>
</tr>
<tr>
<td><strong>1984</strong></td>
<td>Ada Workshop</td>
</tr>
<tr>
<td></td>
<td>1985</td>
</tr>
<tr>
<td></td>
<td>Requirements Inspections</td>
</tr>
<tr>
<td></td>
<td>1986</td>
</tr>
<tr>
<td></td>
<td>FSC Practices &amp; Measurements</td>
</tr>
<tr>
<td><strong>1988</strong></td>
<td>SW Technology Steering Group</td>
</tr>
<tr>
<td></td>
<td>Organizational Operating Procedures</td>
</tr>
<tr>
<td><strong>1990</strong></td>
<td>SW Engineering Process Group Formed</td>
</tr>
<tr>
<td></td>
<td>First SW-CMM® Assessment (Level 3)</td>
</tr>
<tr>
<td></td>
<td>Formal Estimation Procedures</td>
</tr>
<tr>
<td><strong>1991</strong></td>
<td>Market Driven Quality</td>
</tr>
<tr>
<td></td>
<td>Reuse Focus</td>
</tr>
<tr>
<td><strong>1992</strong></td>
<td>Defect Prevention Process</td>
</tr>
<tr>
<td><strong>1993</strong></td>
<td>Integrated Teams</td>
</tr>
<tr>
<td></td>
<td>Standard Development Environment</td>
</tr>
<tr>
<td><strong>1994</strong></td>
<td>Integrated Process Group</td>
</tr>
<tr>
<td></td>
<td>Automated Metrics (MAX)</td>
</tr>
<tr>
<td></td>
<td>Process Coordination Group</td>
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<tr>
<td><strong>1995-6</strong></td>
<td>Integrated Process Library</td>
</tr>
<tr>
<td></td>
<td>ISO 9001 Registration</td>
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<tr>
<td></td>
<td>Software CMM® Level 4</td>
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<tr>
<td><strong>1997-9</strong></td>
<td>ISO 14001 Registration, AS9000 and DCMA ISO 9001 qualification</td>
</tr>
<tr>
<td></td>
<td>Software CMM® Level 5</td>
</tr>
<tr>
<td><strong>2000-2</strong></td>
<td>ISO 9001: 2000 Certification</td>
</tr>
<tr>
<td></td>
<td>EIA-731 Level 3</td>
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<tr>
<td></td>
<td>CMMI® SE/SW/IPPD/SS Level 5</td>
</tr>
</tbody>
</table>
Our quality improved as our maturity increased.
Process Improvement Return-on-Investment Summary

Note: Other initiatives underway during this period include

- ISO 9001 registration, followed by AS9000
- Integrated Teaming, and creation of an Integrated Process Library
- Integration of Systems Engineering and SW Engineering

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Metric</th>
<th>SW-CMM® Level 3</th>
<th>SW-CMM® Level 4</th>
<th>SW-CMM® Level 5</th>
<th>CMMI® Level 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>Defects/MDSS</td>
<td>600</td>
<td>300</td>
<td>150</td>
<td>51</td>
</tr>
<tr>
<td>Productivity</td>
<td>ESS/Labor Month</td>
<td>220</td>
<td>280</td>
<td>340</td>
<td>379</td>
</tr>
<tr>
<td>Cost &amp; Schedule</td>
<td>+- Variance</td>
<td>15%</td>
<td>10%</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>Rework</td>
<td>expressed as a % of industry avg</td>
<td>6%</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Reuse</td>
<td>Percent</td>
<td>68%</td>
<td>75%</td>
<td>82%</td>
<td>82%</td>
</tr>
</tbody>
</table>
We use defect data from formal inspections to project product quality.

We take corrective actions if projections show a deviation from the goals.

In this case, representing an actual program, Latent Defect Rate = 0.51 Defects / Thousand Equivalent Source Statements

Latent Defect Projection Model
(best fit to Exponential, Inflected-S, Rayleigh)

We produce high quality products by monitoring the quality level throughout the program’s performance.
LM Maritime Systems & Sensors – Undersea Systems
Software Quality

Product Quality Level is in Five Sigma Range

<table>
<thead>
<tr>
<th>Sigma</th>
<th>Defects/MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>690,000.0</td>
</tr>
<tr>
<td>2</td>
<td>308,537.0</td>
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<tr>
<td>3</td>
<td>66,807.0</td>
</tr>
<tr>
<td>4</td>
<td>6,210.0</td>
</tr>
<tr>
<td>5</td>
<td>233.0</td>
</tr>
<tr>
<td>6</td>
<td>3.4</td>
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</table>

MS = Million
Source Statements

Our quality rate is 20 times better than the average industry rates.

5 Sigma
LM Maritime Systems & Sensors – Undersea Systems
Software Productivity vs. SW-CMM® Maturity Level

Product Productivity Percent Improvement
Delivered Source Lines of Code per Labor Month
All Languages

Level 1
Level 2
Level 3
Level 4,5

Level 1
Level 2
Level 3
Level 4,5

0% 50% 100% 150% 200% 250% 300% 350% 400%

Cost & Schedule Estimates vs. Actuals at Maturity Level 5

Cost Performance Index (CPI) & Schedule Performance Index (SPI)

Data from 8 programs in 2Q 2003

Reference: “A Correlational Study of the CMM® and Software Development Performance”
Lawlis, Flowe & Thordahl, CROSSTALK, September 1995
Summary

- At Lockheed Martin, benefits derived during SW-CMM® implementation continue to be realized as CMMI® maturity evolves
- Allocating benefits to their sources is difficult when implementing multiple models/standards
- SW-CMM® and CMMI® are viewed as significant (but not sole) contributors to process improvement return-on-investment (ROI) to date
Contact Information

Joan Weszka
Lockheed Martin Mission Systems
Systems & Software Resource Center
(301) 240-7013 / Fax 240-7009
joan.weszka@lmco.com
Acronyms

- ARC – Appraisal Requirements for CMMI®
- CAM - Continuous Appraisal Method
- CMMI® - Capability Maturity Model Integration
- ESLOC or ESS – Equivalent SLOC/SS; a normalized value derived from new development, plus SLOC/SS that are modified, retained, ported, etc.
- IPPD - Integrated Product and Process Development
- LM - Lockheed Martin
- LM-IEP - Lockheed Martin Integrated Engineering Process
- OSP – Organizational Standard Process
- PA - Process Area
- SLOC – Source Line of Code
- SS – Source Statement (sometimes called a “Logical SLOC”)