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

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Agenda

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

CMMI® Process Requirements

ARC* Class A Appraisal Requirements*

CAM is an ARC Class A appraisal method.

CAM

Lockheed Martin Integrated Engineering Process

* Appraisal Requirements for CMMI® (ARC)
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

OSP = Organizational Standard Process
PA = Process Area
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 SM Appraisal
  - Achieved target profile 3 for CMMI®-SE/SW

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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

![Graph showing software productivity over years with a line of best fit and data points labeled Level 3 CMM®, Level 4 CMM®, and Level 3 CMMI®.](image)
LM Maritime Systems & Sensors Radar Systems

Process Improvement Credentials

- SW-CMM® level 5 (CBA IPI^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® began in 2000
- CMMI®-SE/SW/IPPD target profile 4 (CAM) in Nov. 2002

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LM Maritime Systems & Sensors Radar Systems
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+\%.
LM Maritime Systems & Sensors – Undersea Systems

Process Credentials

- Systems & Software Engineering*
  - Software CMM® Level 4 (CBA IPI℠) - June 1995
  - Software CMM® Level 5 (CBA IPI℠) - 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

1970s
Top-down Structured Programming
Design & Code Inspections
1980-2
Functional Decomposition
SW Engineering Workshop
Advanced Design Workshop
1983
SW Management Workshop
1984
Ada Workshop
1985
Requirements Inspections
1986
FSC Practices & Measurements
1988
SW Technology Steering Group
Organizational Operating Procedures
1990
SW Engineering Process Group Formed
First SW-CMM® Assessment (Level 3)
Formal Estimation Procedures

1991
Market Driven Quality
Reuse Focus

1992
Defect Prevention Process

1993
Integrated Teams
Standard Development Environment
Integrated Process Group
1994
Automated Metrics (MAX)
Process Coordination Group (PCG)
1995-6
Integrated Process Library
ISO 9001 Registration
Software CMM® Level 4)
1997-9
ISO 14001 Registration, AS9000 and
DCMA ISO 9001 qualification
Software CMM® Level 5
2000-2
ISO 9001: 2000 Certification
EIA-731 Level 3
CMMI® SE/SW/IPPD/SS Level 5
Our quality improved as our maturity increased.
LM Maritime Systems & Sensors – Undersea Systems
Process Improvement Return-on-Investment Summary

<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>
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<tbody>
<tr>
<td>Quality</td>
<td>Defects/MDSS</td>
<td>600</td>
<td>300</td>
<td>150</td>
<td>51</td>
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<tr>
<td>Productivity</td>
<td>ESS/Labor Month</td>
<td>220</td>
<td>280</td>
<td>340</td>
<td>379</td>
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<tr>
<td>Cost &amp; Schedule</td>
<td>15% Variance</td>
<td>15%</td>
<td>10%</td>
<td>8%</td>
<td>8%</td>
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<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>

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

We use defect data from formal inspections to project product quality.

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

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>
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<th>Sigma</th>
<th>Defects/MS</th>
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<tr>
<td>1</td>
<td>690,000.0</td>
</tr>
<tr>
<td>2</td>
<td>308,537.0</td>
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<td>3</td>
<td>66,807.0</td>
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<td>4</td>
<td>6,210.0</td>
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<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.
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
Cost Performance Index (CPI) & Schedule Performance Index (SPI)

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

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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”)}