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
  - LM Systems Integration (Owego, NY)
  - LM Maritime Systems & Sensors – Tactical Systems (Eagan, MN)
  - 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

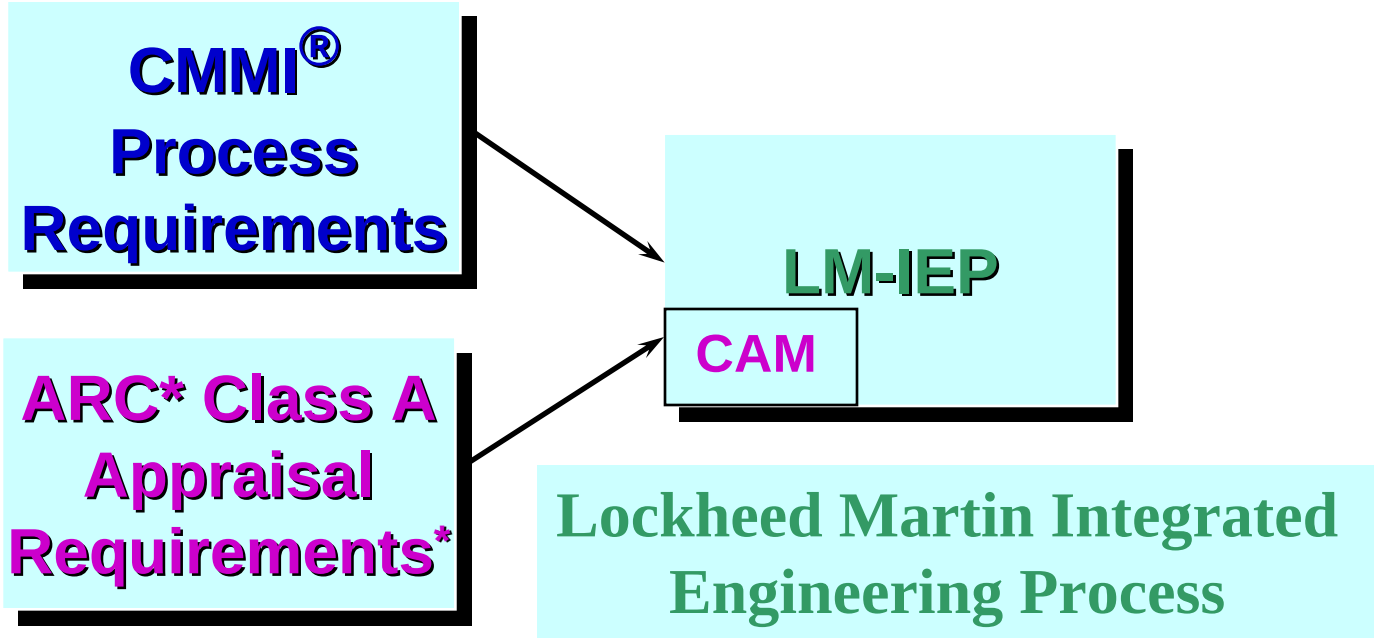
Lockheed Martin's Integrated Engineering Process Standard is being deployed under corporate policy.

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

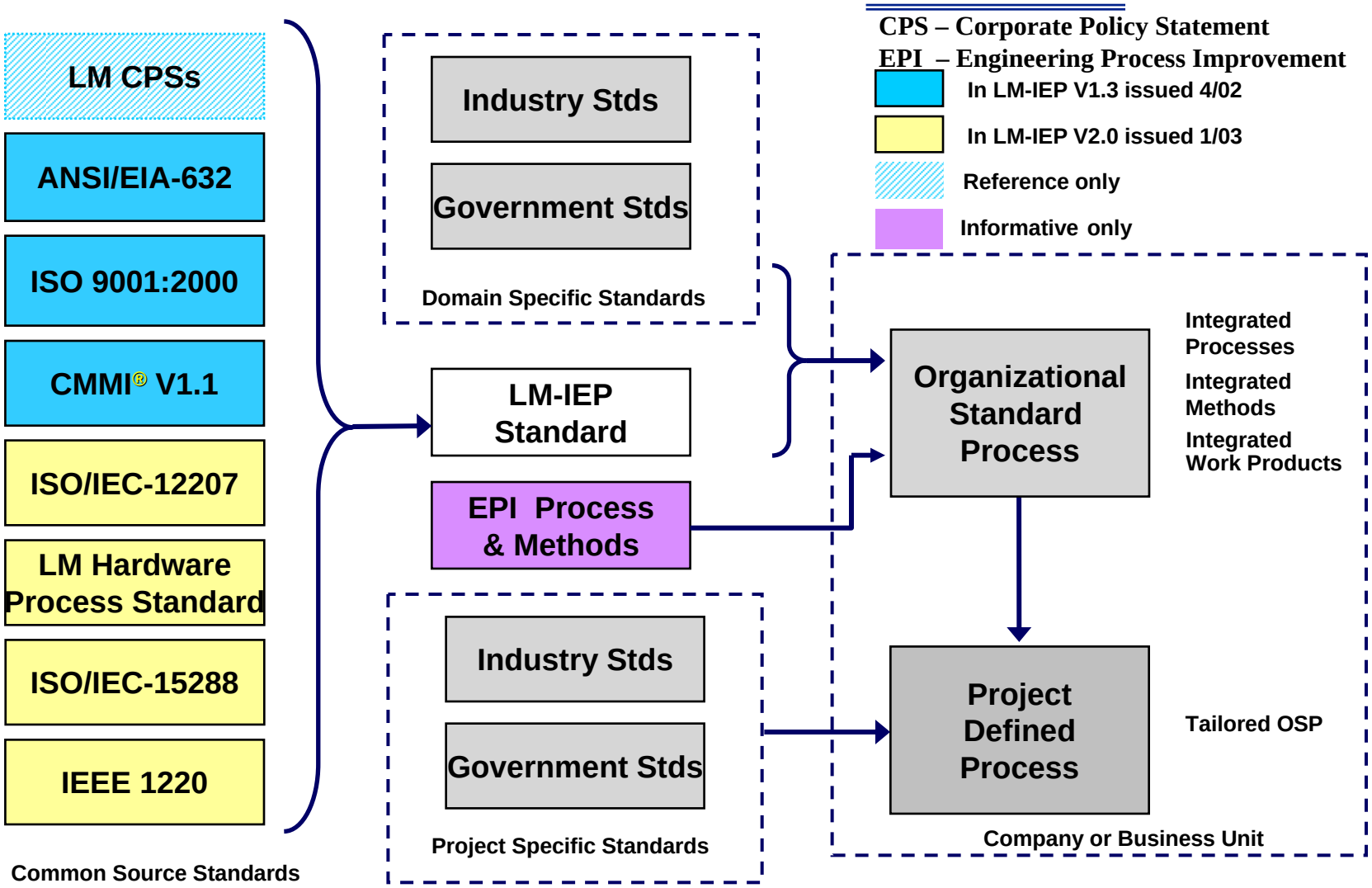
- CMMI® provides a set of integrated process and appraisal method requirements



CAM is an ARC Class A appraisal method.

*** Appraisal Requirements for CMMI® (ARC)**

LM-IEP Context Diagram

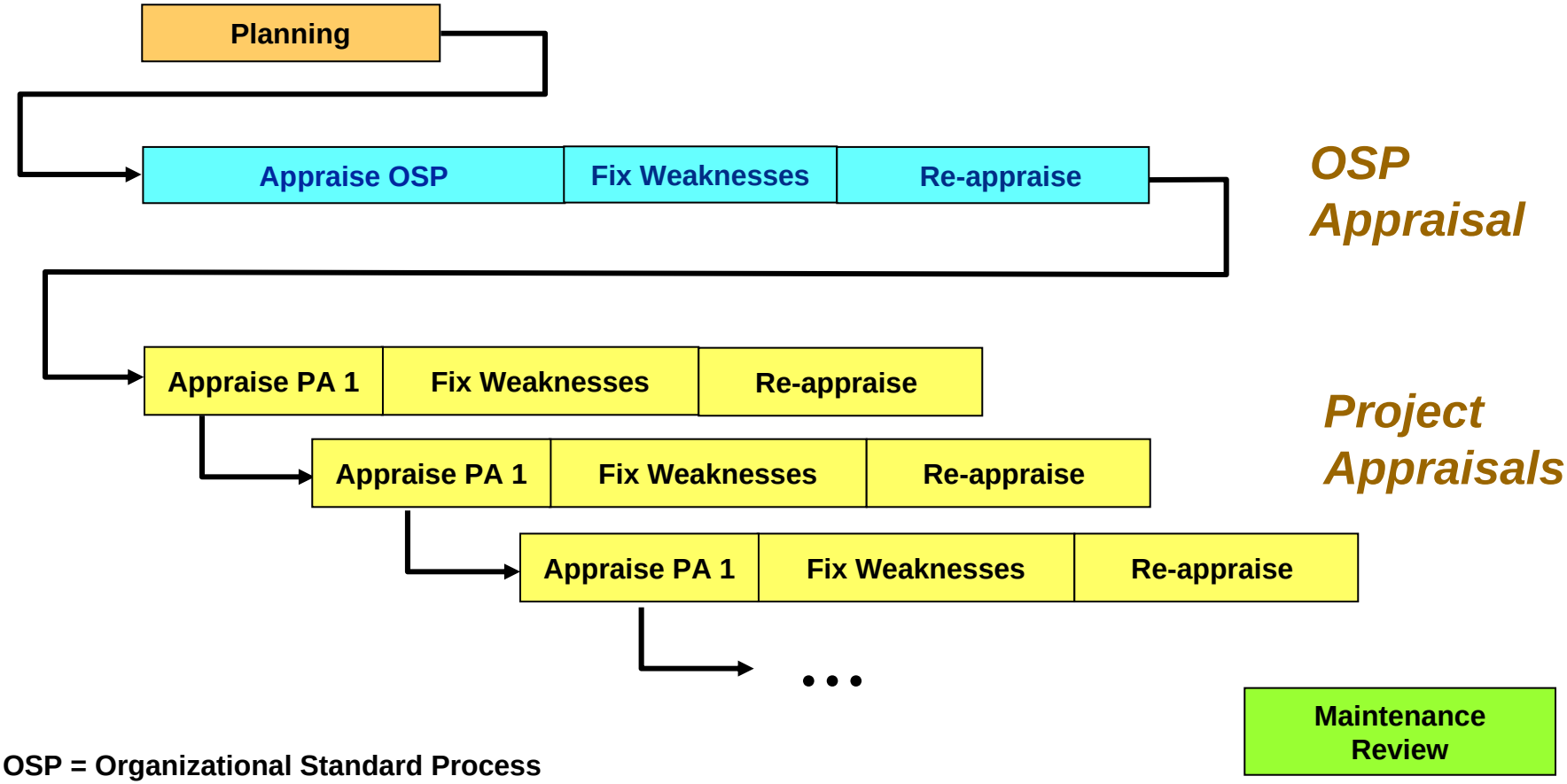


Continuous Appraisal Method (CAM) Design Goals

- 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



OSP = Organizational Standard Process
PA = Process Area

Institutionalization focus with minimal project disruption

Feedback on CAM usage

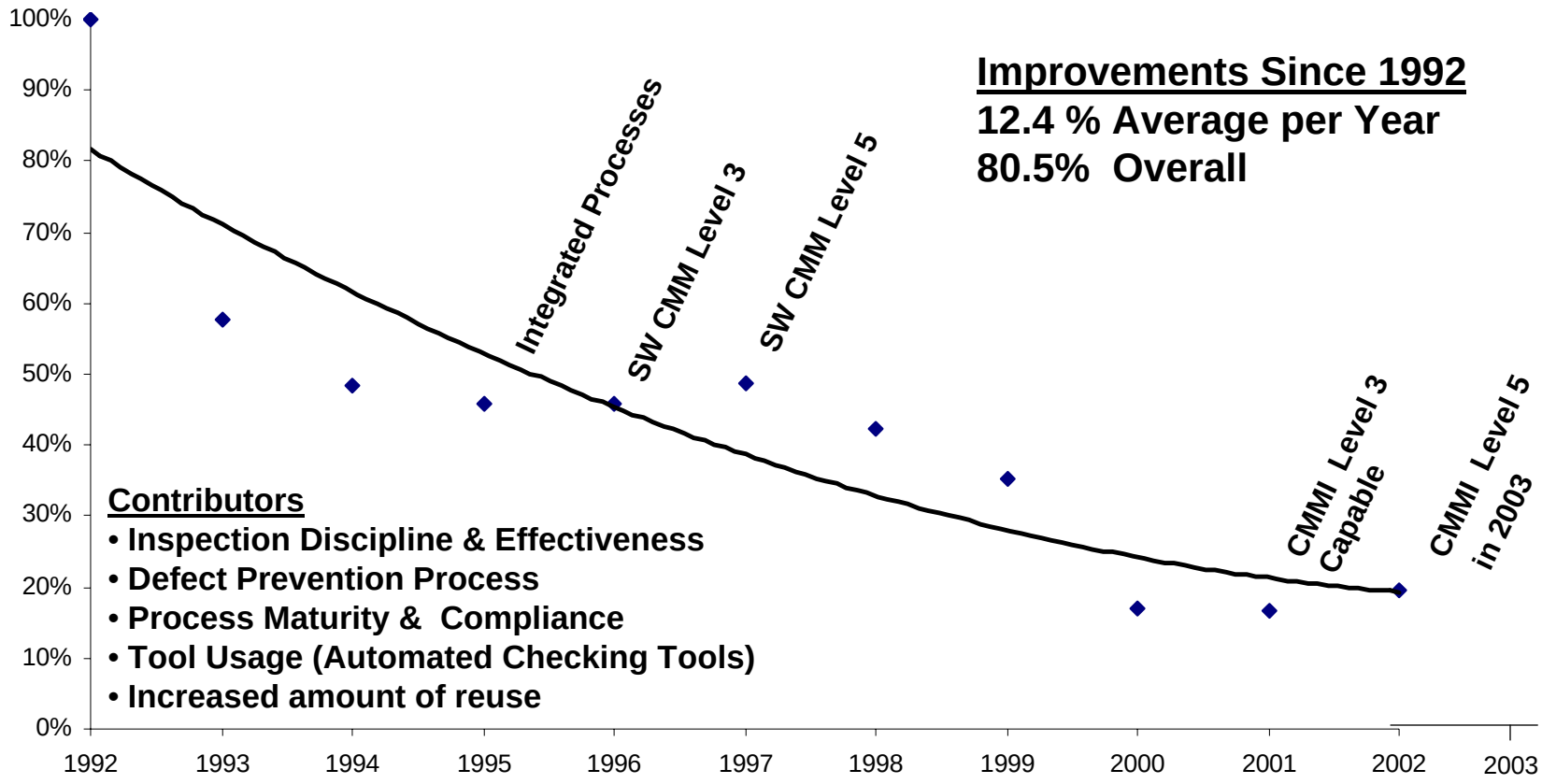
- CAM has been or is being deployed at 12 Lockheed Martin operating units using CMMI®
  - 6 prior CAMs have been completed using EIA/IS 731
- Experience with CAM has been positive:
  - More focus on process improvement
  - Less invasive to programs
  - Less stressful to the organization
  - More value-add,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

Lockheed Martin Systems Integration - Owego Process Credentials

2003	CMMI Level 5 / AS 9100A	2003
2002	Q-100 Award	2002
2001	ISO 9001:2000 / SEI CMMI Pilot Site	2001
2000	Lean / Six Sigma	2000
1998	LM21 Best Practices	1998
1997	SW CMM Level 5	1997
1996	ISO 9001:1994 / SW CMM Level 3	1996
1995	RIT / USA TODAY Quality Cup Finalist	1995
1994	New York State Excelsior Award	1994
1993	IBM Baldrige Gold Award	1993
1990	TQM	1990

Lockheed Martin Systems Integration

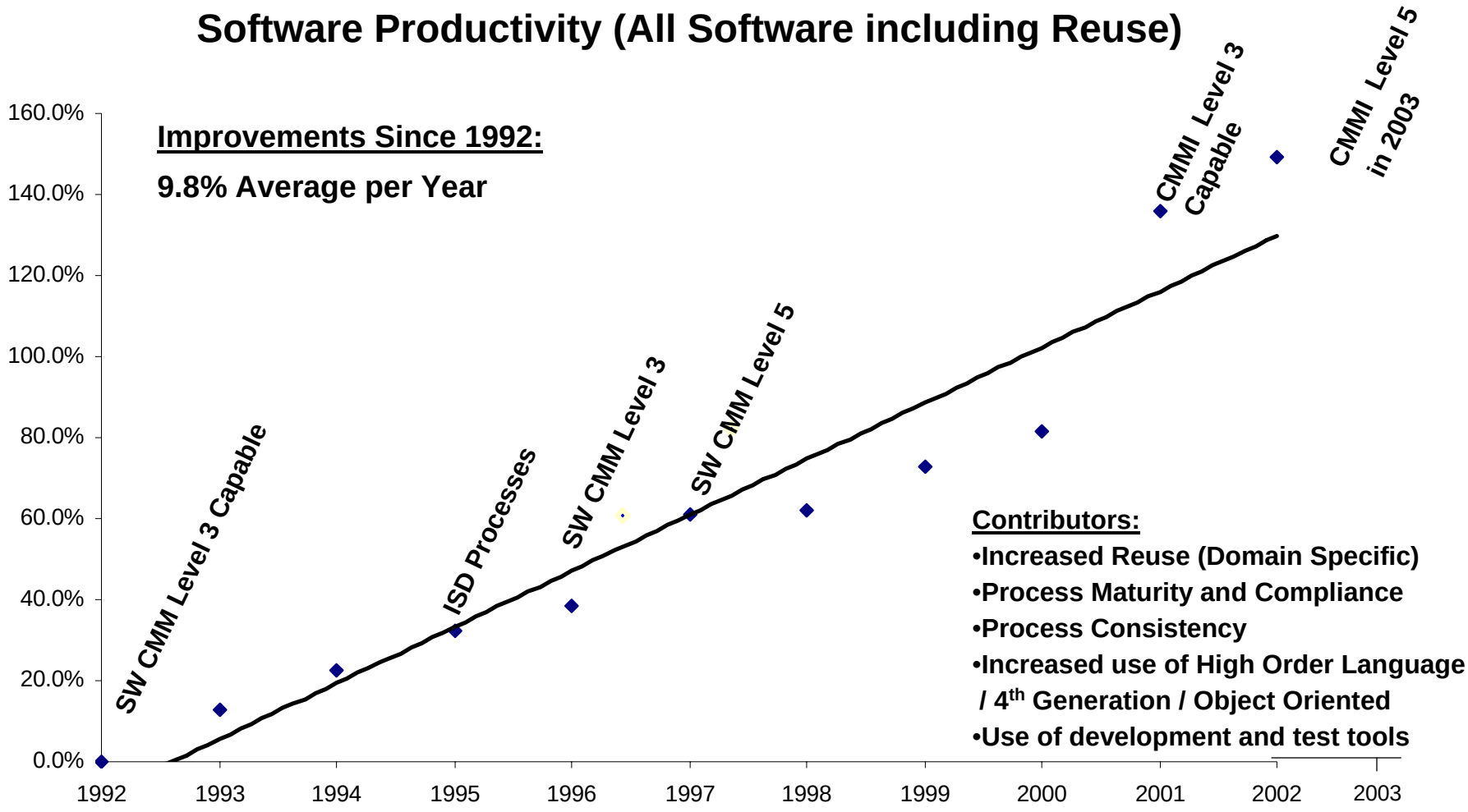
% Improvement in Software Defects per Million Delivered Source Lines of Code



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)



LM Maritime Systems & Sensors Tactical Systems Process Improvement Credentials

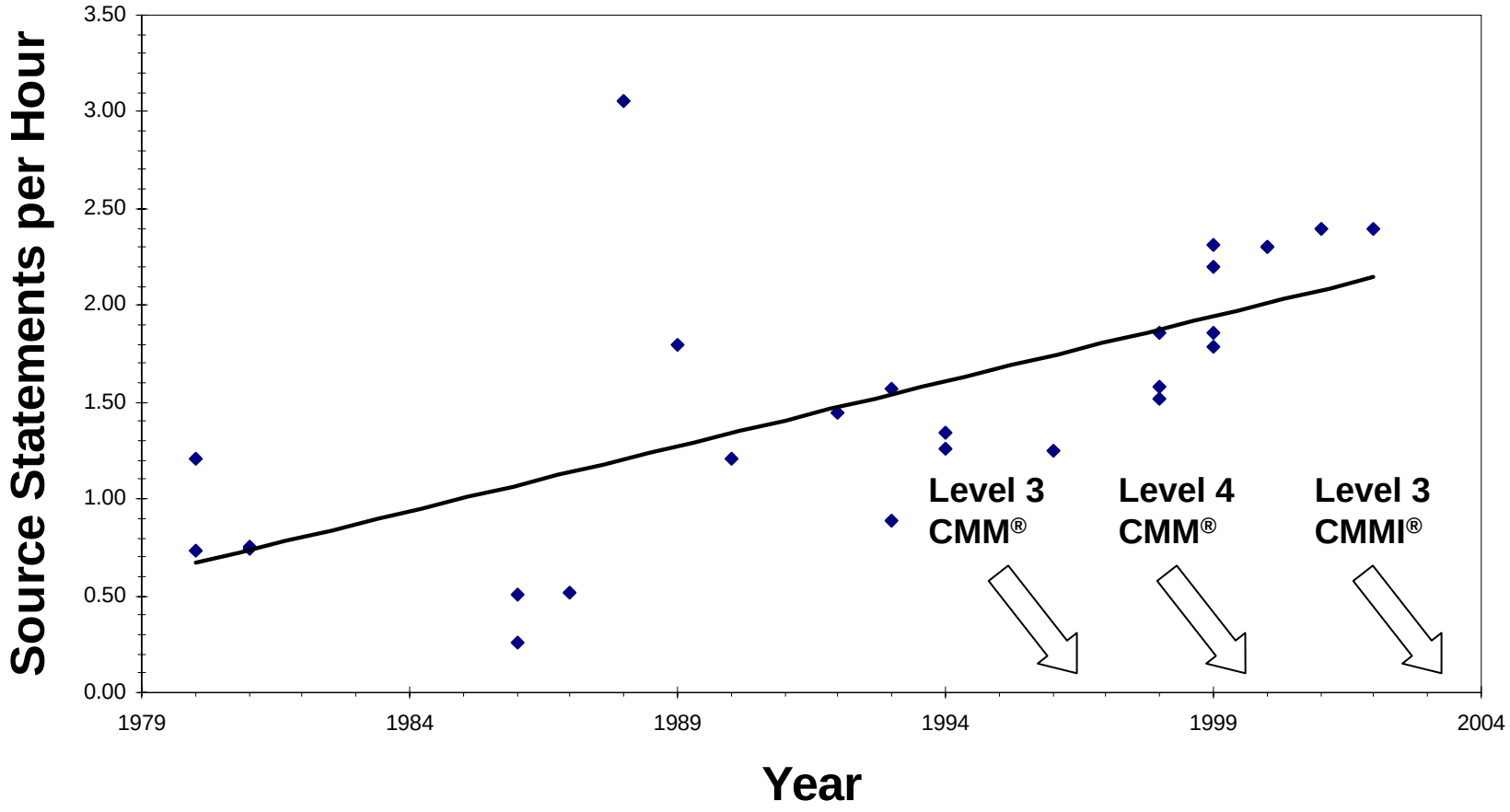
- Oct. 1999 – Attained SW-CMM® level 4
- Dec. 2000 – Attained Systems Engineering Capability Model (EIA 731) level 3
- Jan. 2001
  - Began focus on integrated process improvement
  - Began transition to CMMI®
- June 2002 – May 2003 CAM Appraisal
  - OSP: Target profile 5 for CMMI®-SE/SW/IPPD/SS
  - Projects: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



LM Maritime Systems & Sensors Radar Systems Process Improvement Credentials

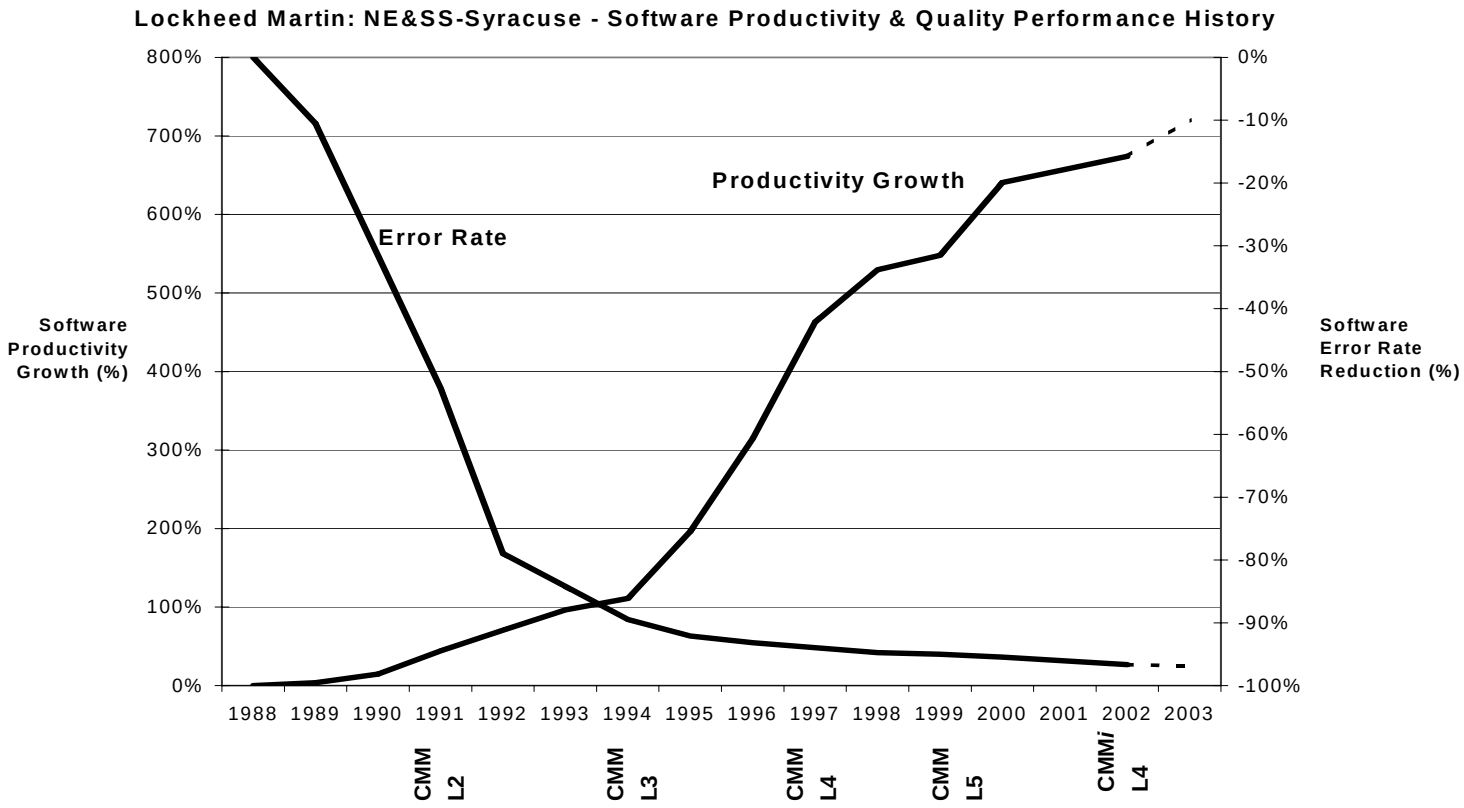
- SW-CMM® level 5 (CBA IPI℠) in Dec. 1999
- Systems Engineering Capability Model (EIA/IS 731) level 3+ (CAM) in Dec. 1999
- Focus on integrated process improvement including hardware began in 2000
- Transition to CMMI® began in 2000
- CMMI®-SE/SW/IPPD target profile 4 (CAM) in Nov. 2002

® SW-CMM and CMMI are registered in the U.S. Patent and Trademark Office by Carnegie Mellon University.

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

LM Maritime Systems & Sensors Radar Systems Software Productivity and Quality



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+%.

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LM Maritime Systems & Sensors – Undersea Systems Process Credentials

- Systems & Software Engineering*
  - Software CMM® Level 4 (CBA IPI[SM]) - June 1995
  - Software CMM® Level 5 (CBA IPI[SM]) - February 1999
  - CMMI® & EIA-731 Level 3 (CAM) - October 2001
  - CMMI® Level 5 (CAM) - October 2002
- Quality Management
  - ISO 9001:1994 - September 1995
  - AS9000 - November 1997
  - Defense Contract Management Agency (DCMA) ISO 9001 Qualified - December 1997
  - ISO 9001:2000 - December 2000
  - AS9100A – December 2002

[SM] CBA IPI is a service mark of Carnegie Mellon University

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

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)

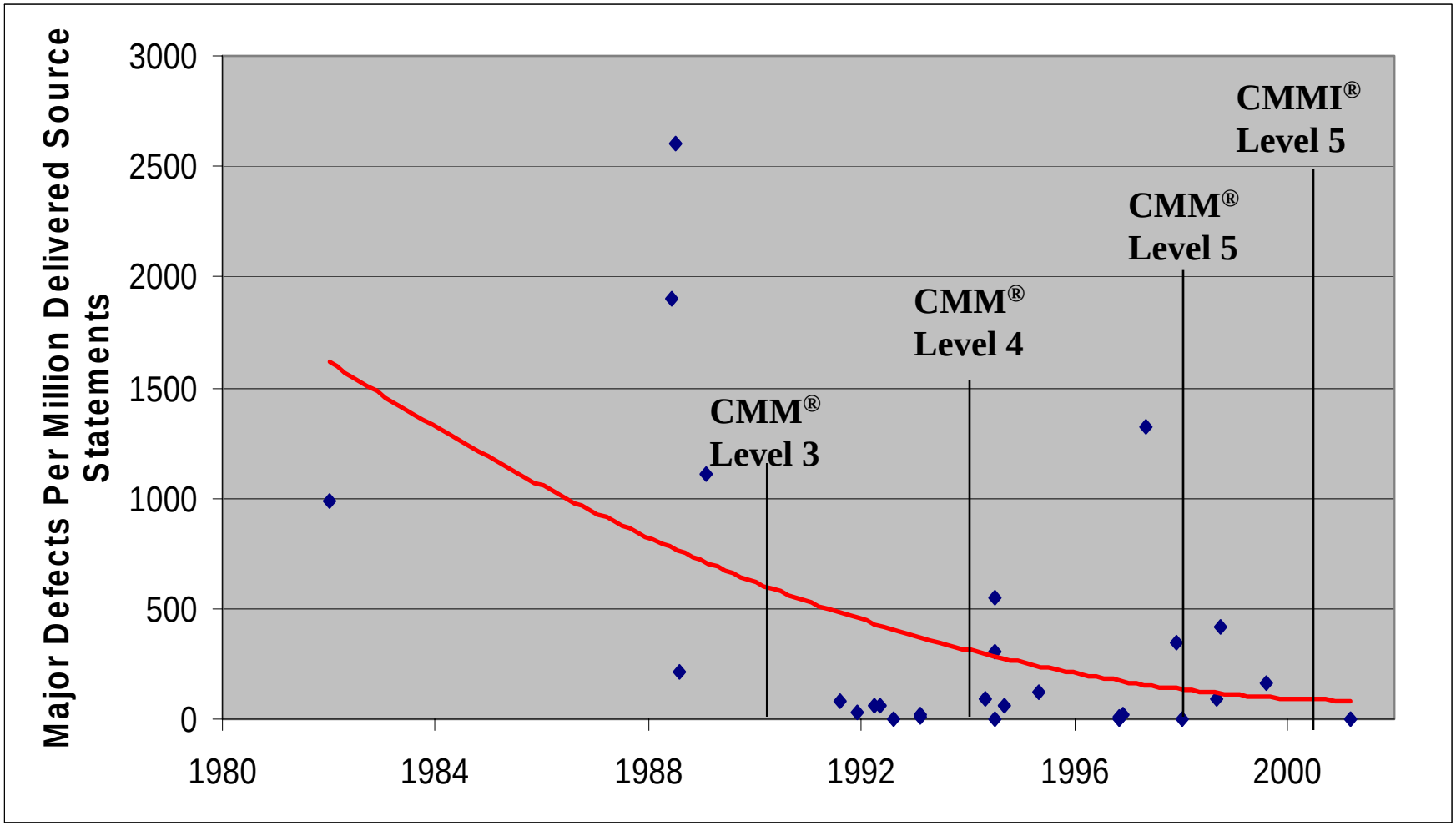
1995-6
- Integrated Process Library
- ISO 9001 Registration
- Software CMM® Level 4)

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

LM Maritime Systems & Sensors – Undersea Systems Software Product Quality (Defect Rate)

Our quality improved as our maturity increased.



LM Maritime Systems & Sensors – Undersea Systems Process Improvement Return-on-Investment Summary

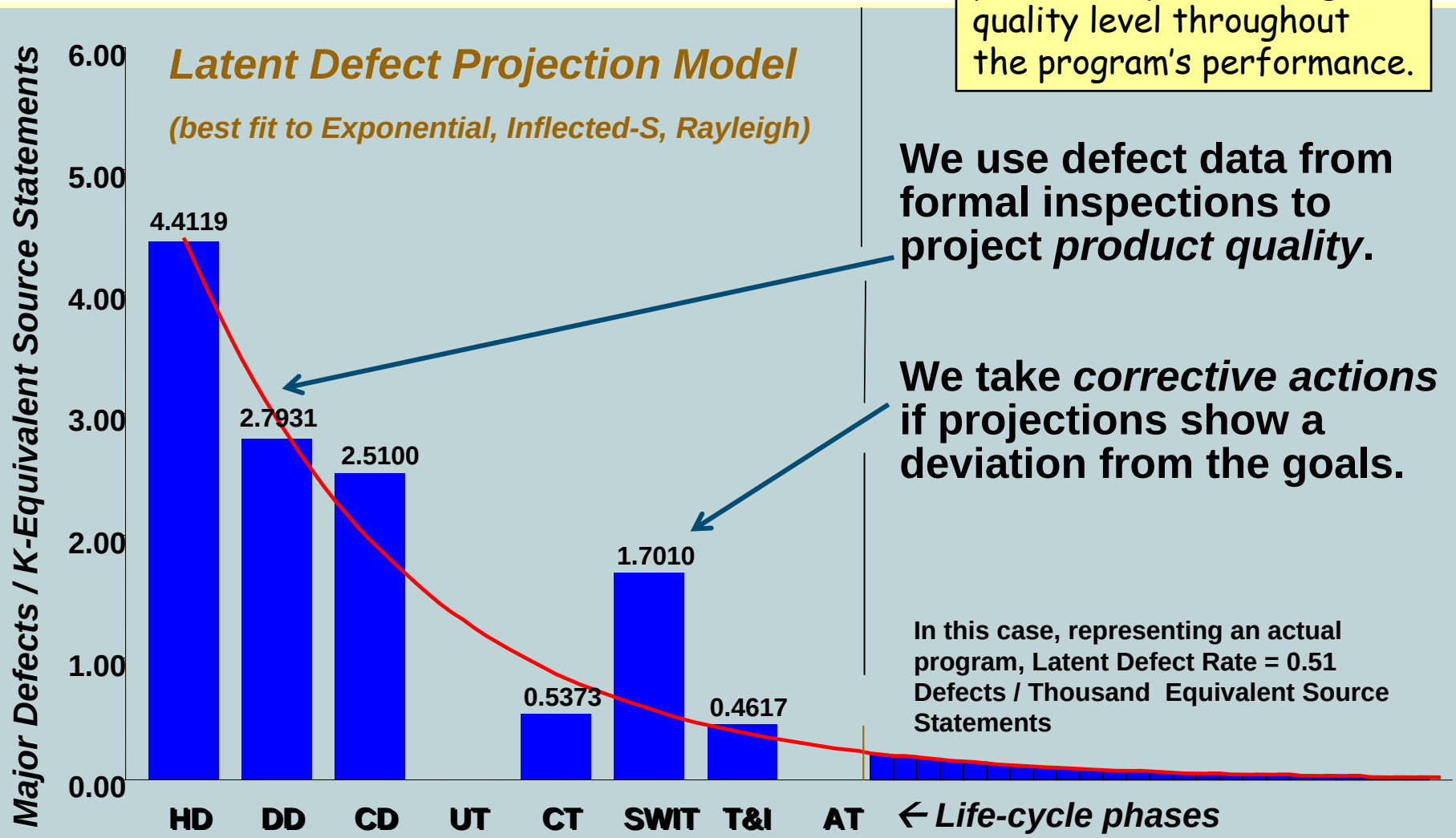
		SW-CMM® Level 3	SW-CMM® Level 4	SW-CMM® Level 5	CMMI® Level 5
Improvement	**Metric**	**1990**	**1995**	**1999**	**2002**
Quality	Defects/MDSS	600	300	150	51
Productivity	ESS/Labor Month	220	280	340	379
Cost & Schedule	+- Variance	15%	10%	8%	8%
Rework	expressed as a % of industry avg	6%	3%	2%	2%
Reuse	Percent	68%	75%	82%	82%

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

LM Maritime Systems & Sensors – Undersea Systems
Product Quality

We produce high quality products by monitoring the quality level throughout the program's performance.



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

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

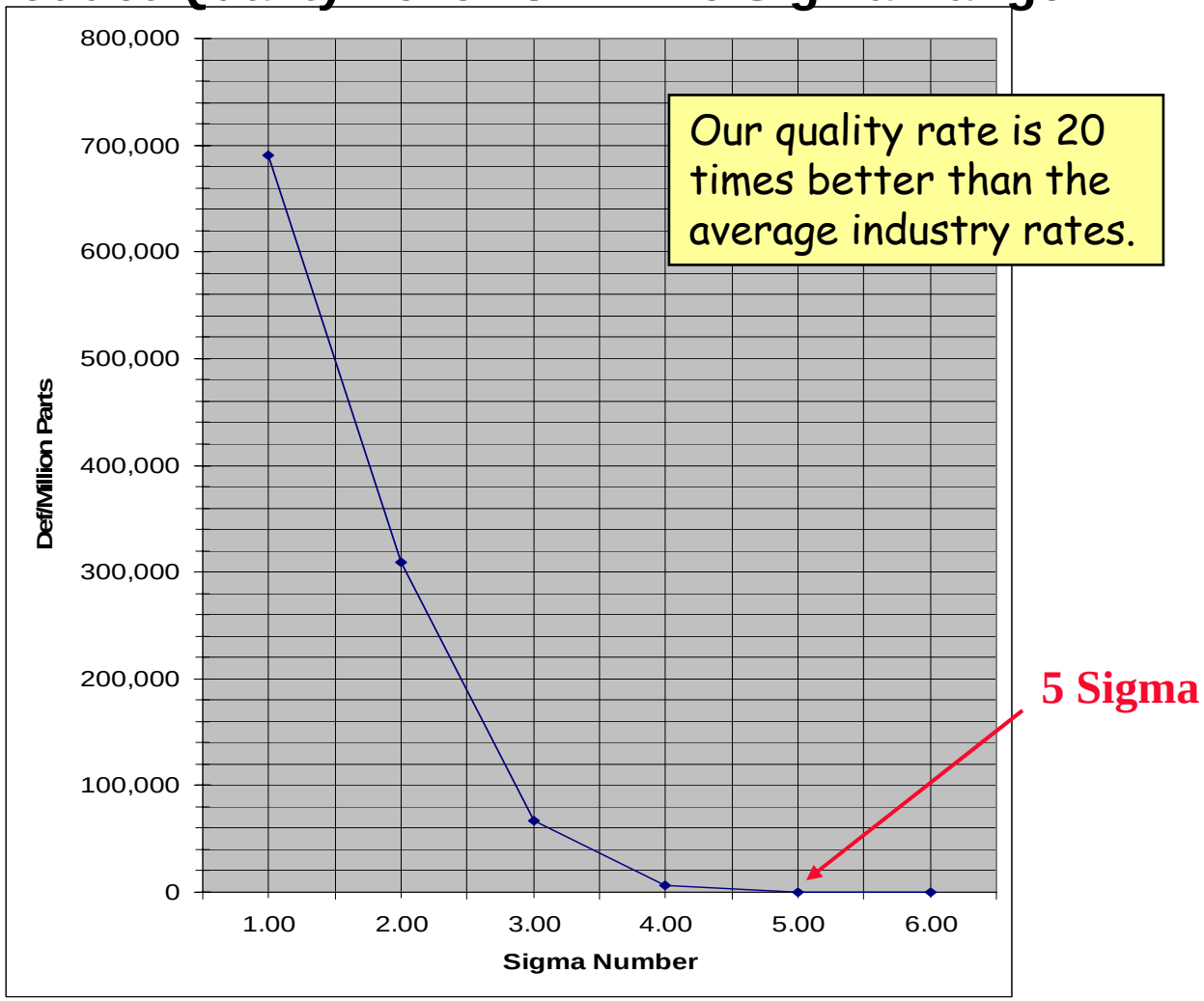
In this case, representing an actual program, Latent Defect Rate = 0.51 Defects / Thousand Equivalent Source Statements

LM Maritime Systems & Sensors – Undersea Systems Software Quality

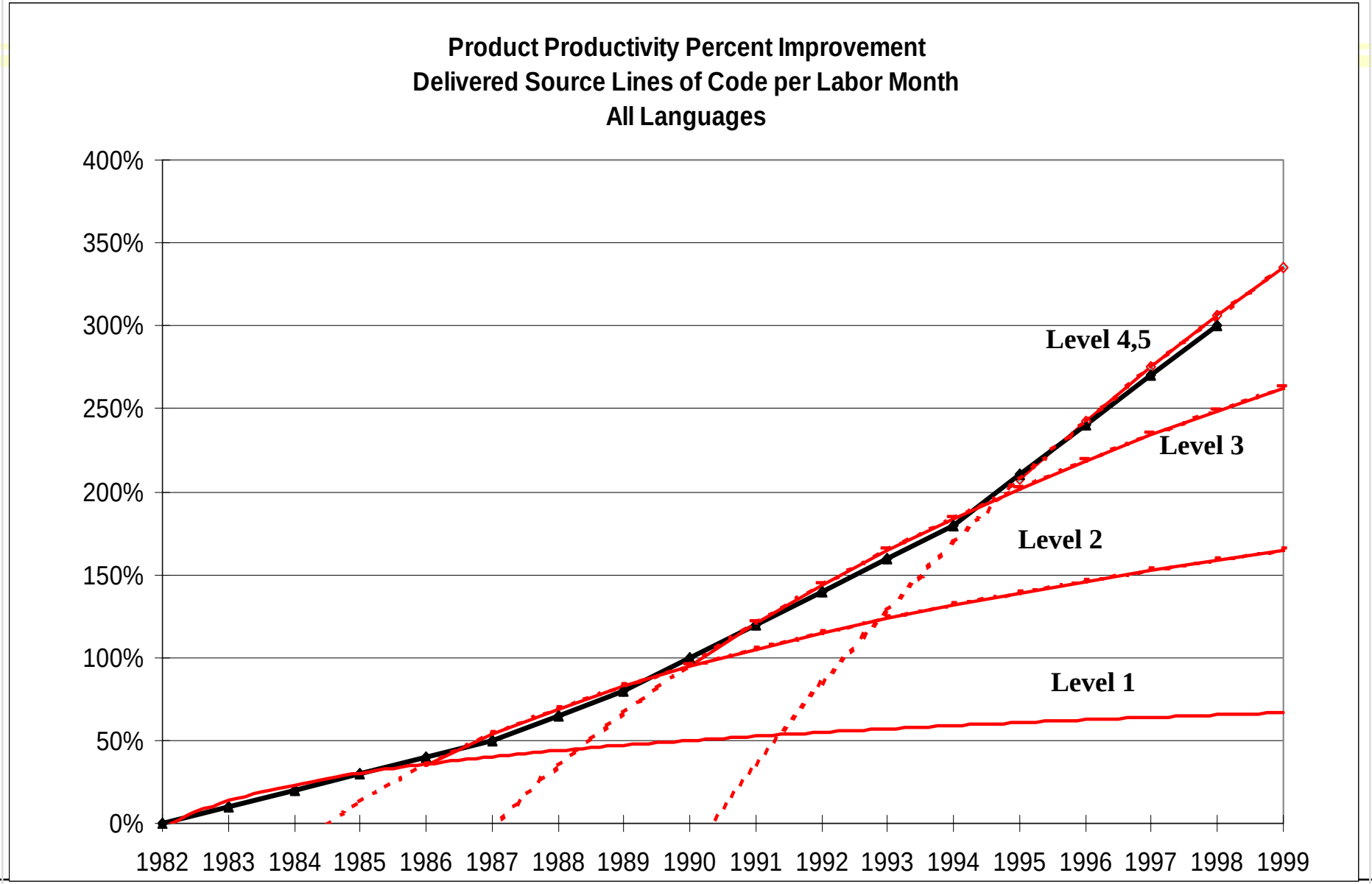
Product Quality Level is in Five Sigma Range

Sigma	Defects/MS
1	690,000.0
2	308,537.0
3	66,807.0
4	6,210.0
5	233.0
6	3.4

MS = Million Source Statements



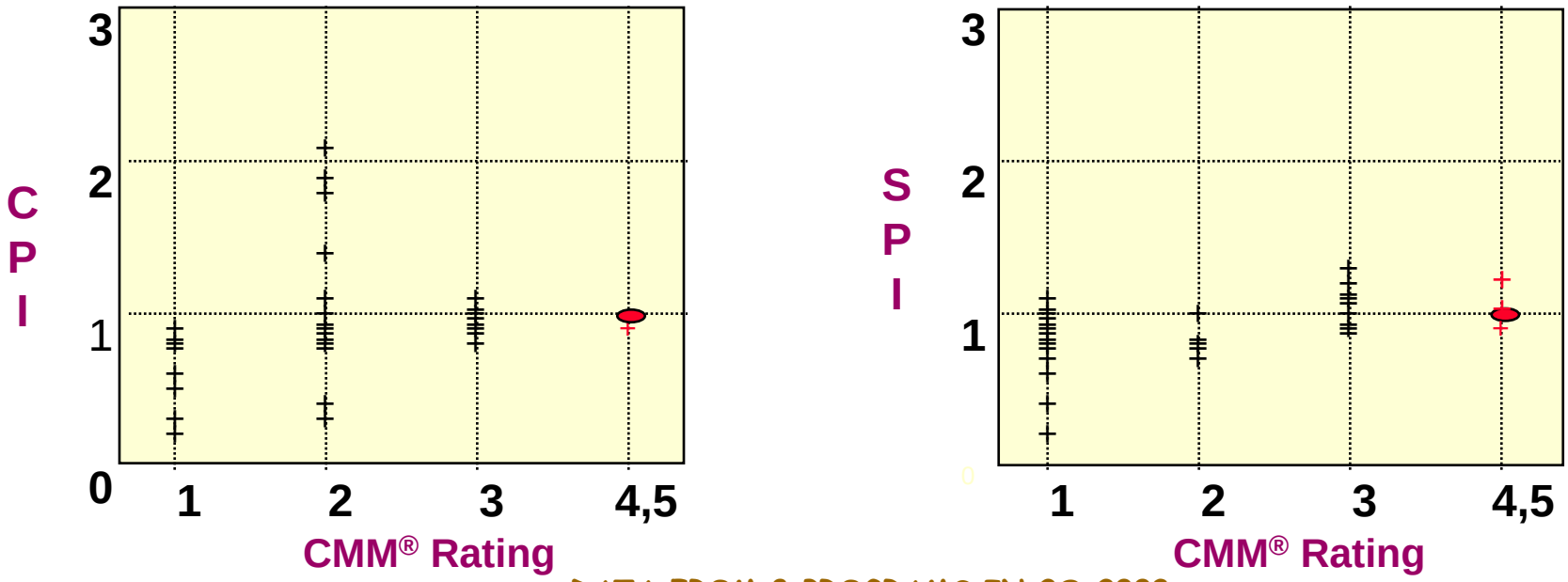
LM Maritime Systems & Sensors – Undersea Systems
Software Productivity vs. SW-CMM® Maturity Level



LM Maritime Systems & Sensors – Undersea Systems Cost & Schedule Estimates vs. Actuals at Maturity Level 5

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

SCATTER PLOTS BETWEEN "1" AND "3" RATINGS ARE INDUSTRY SAMPLES.
LOCKHEED MARTIN DATA HAS BEEN ADDED IN RED.



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

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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”)