

# **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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- **FSCS Program and Problem Overview**
- **Raytheon's Foundation for Process Improvement**
- **Achieving Continuous Improvement on FSCS**

# Act One

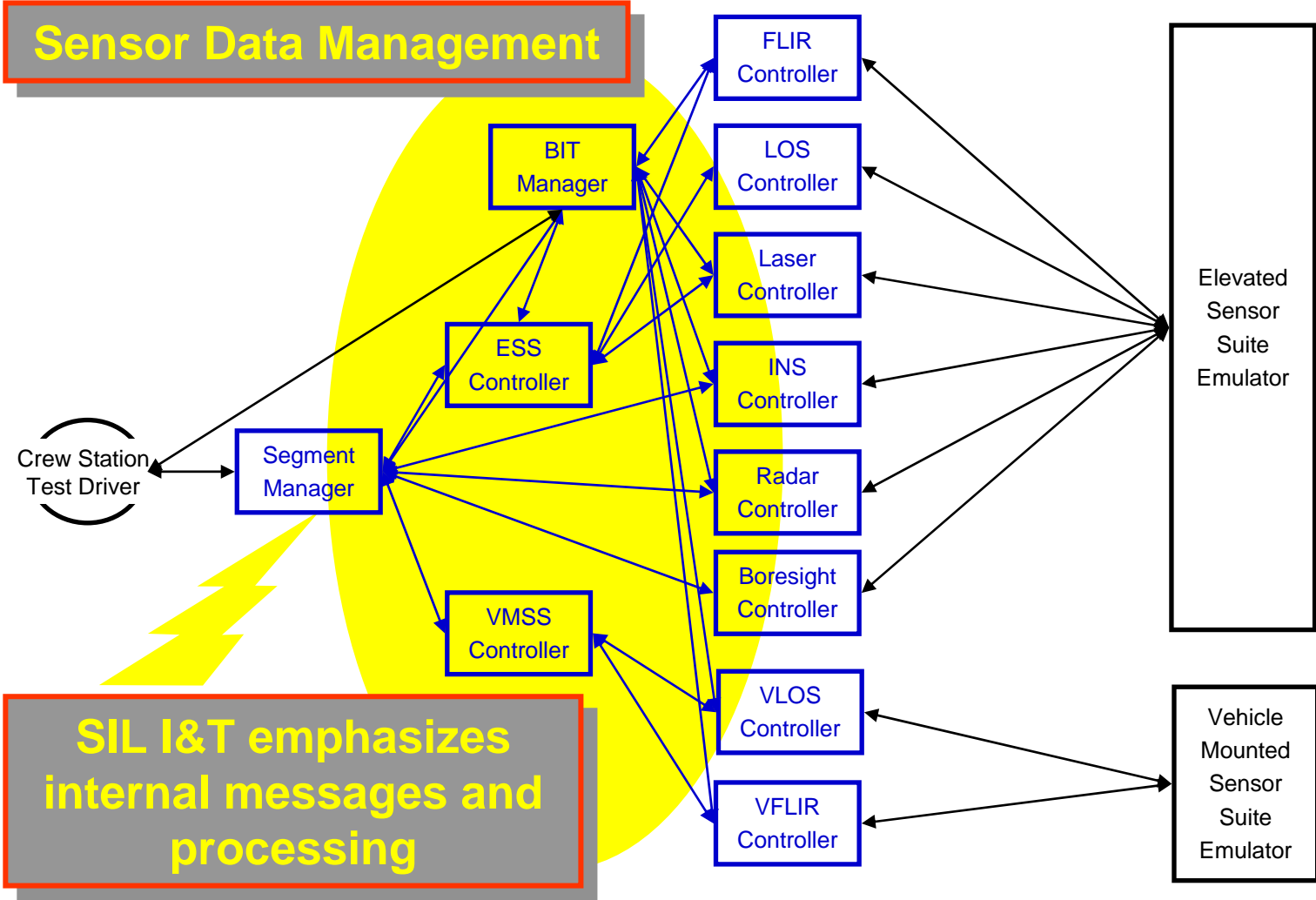
## FSCS Program and Problem Overview

# 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

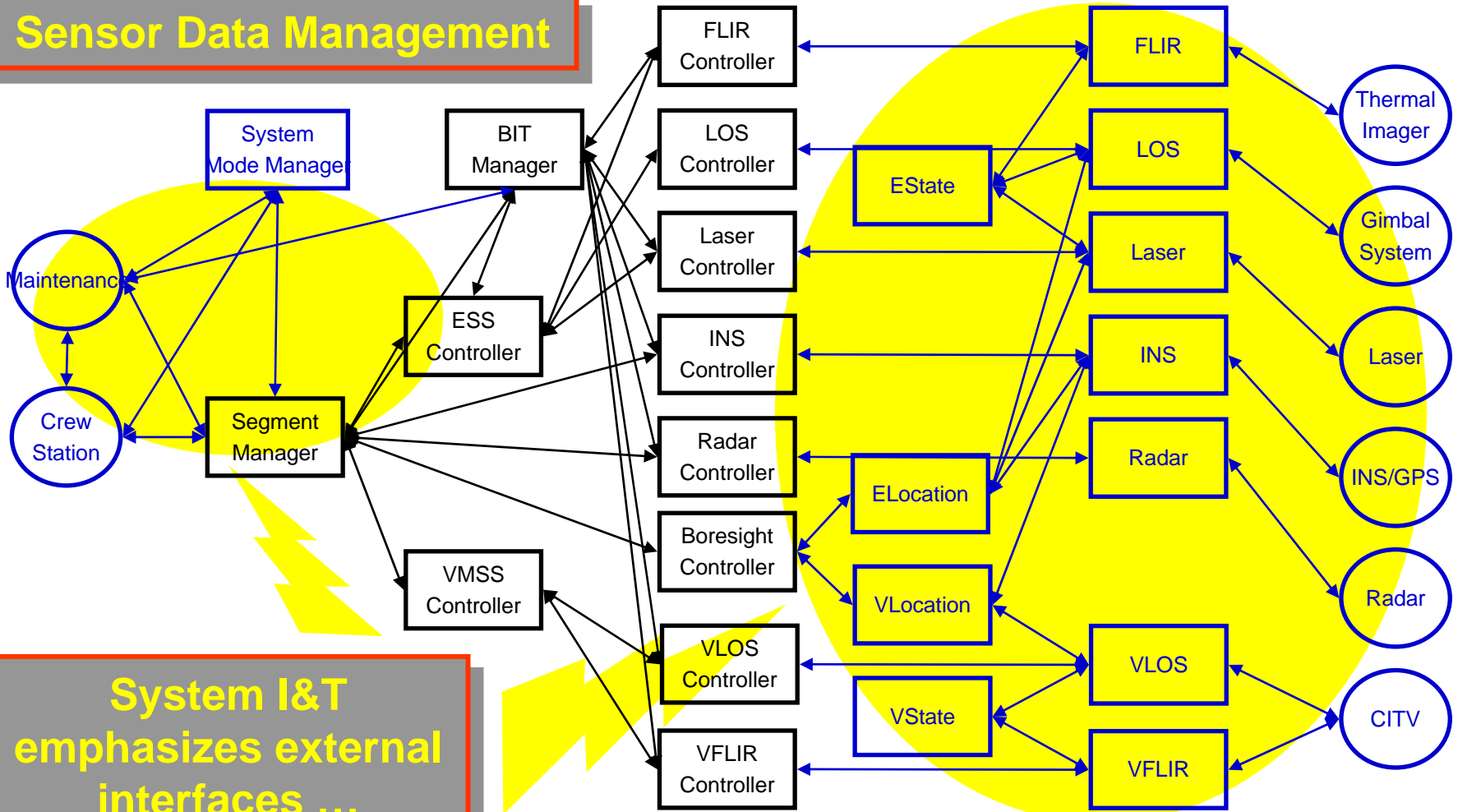


# FSCS Program Overview - SIL I&T



# FSCS Program Overview - System I&T

## Sensor Data Management



System I&T  
emphasizes external  
interfaces ...

- 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	Stage Originated								Totals
Detected	RA	SD	OD	IM	SIL	SIT	AT	Maint	Totals
RA	19								19
SD	10	20							30
OD	8	1	141						150
IM	1	0	3	113					117
SIL	0	0	1	14	34				49
SIT	1	1	6	57	2	21			88
AT	0	0	0	0	0	0	0		0
Maint	0	0	0	0	0	0	0	0	0
Totals	39	22	151	184	36	21	0	0	453
					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**

**Exceeded!**

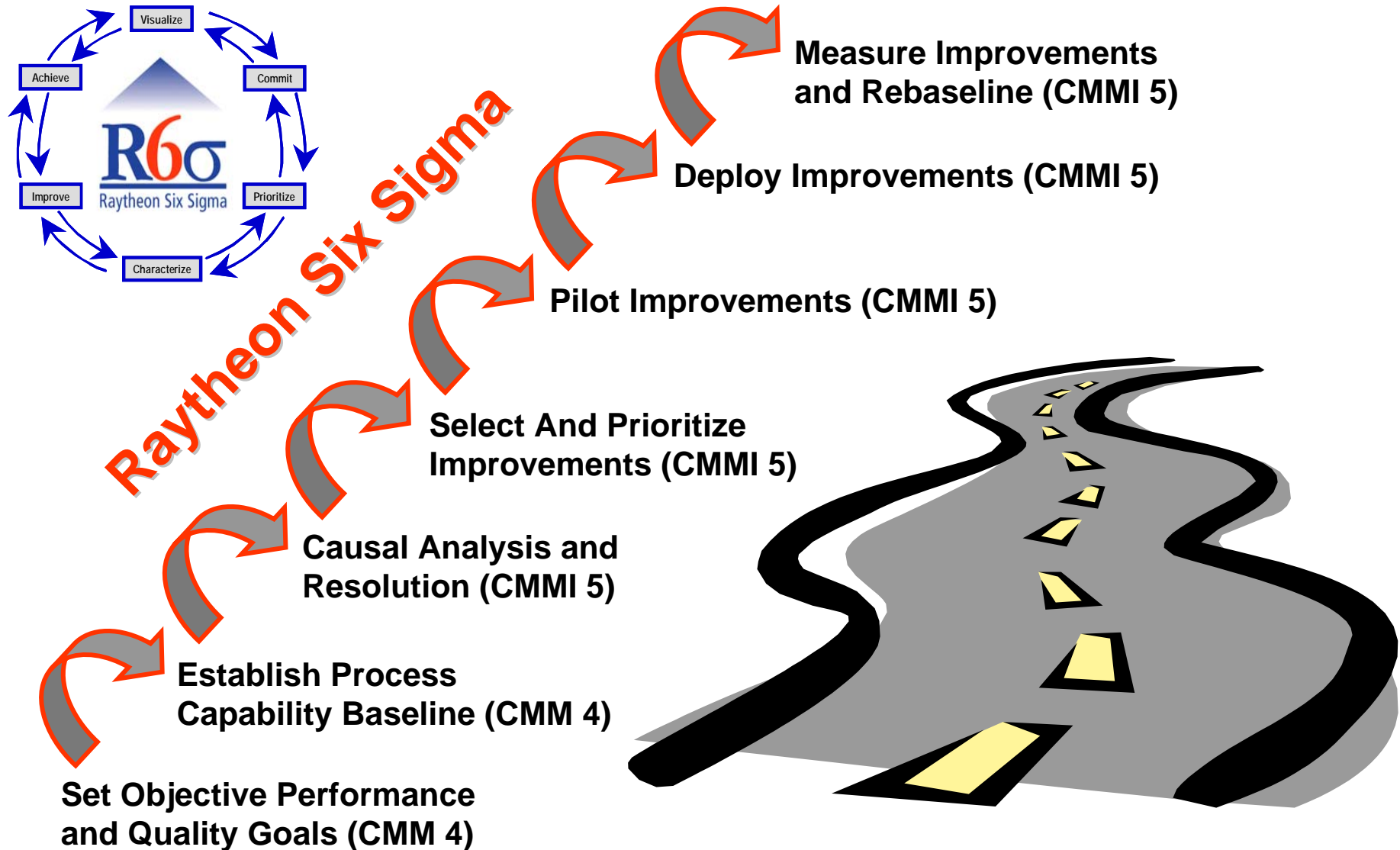
**QPM Thresholds**



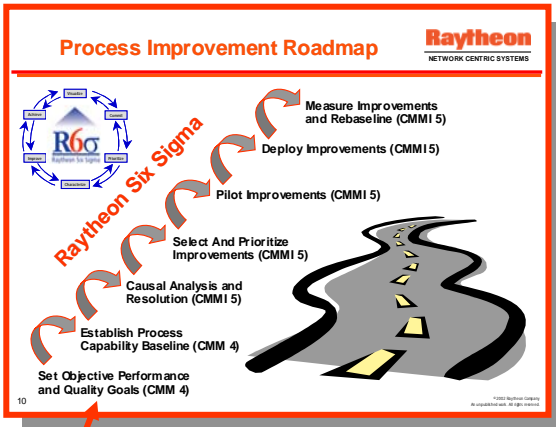
## Act Two

# Raytheon's Foundation for Process Improvement

# Process Improvement Roadmap

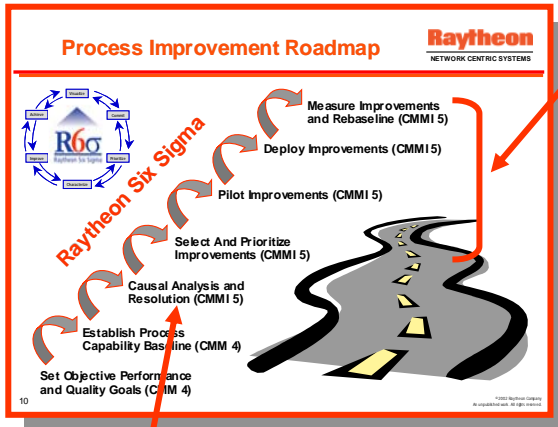


# CMM Level 4 Foundation



## 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



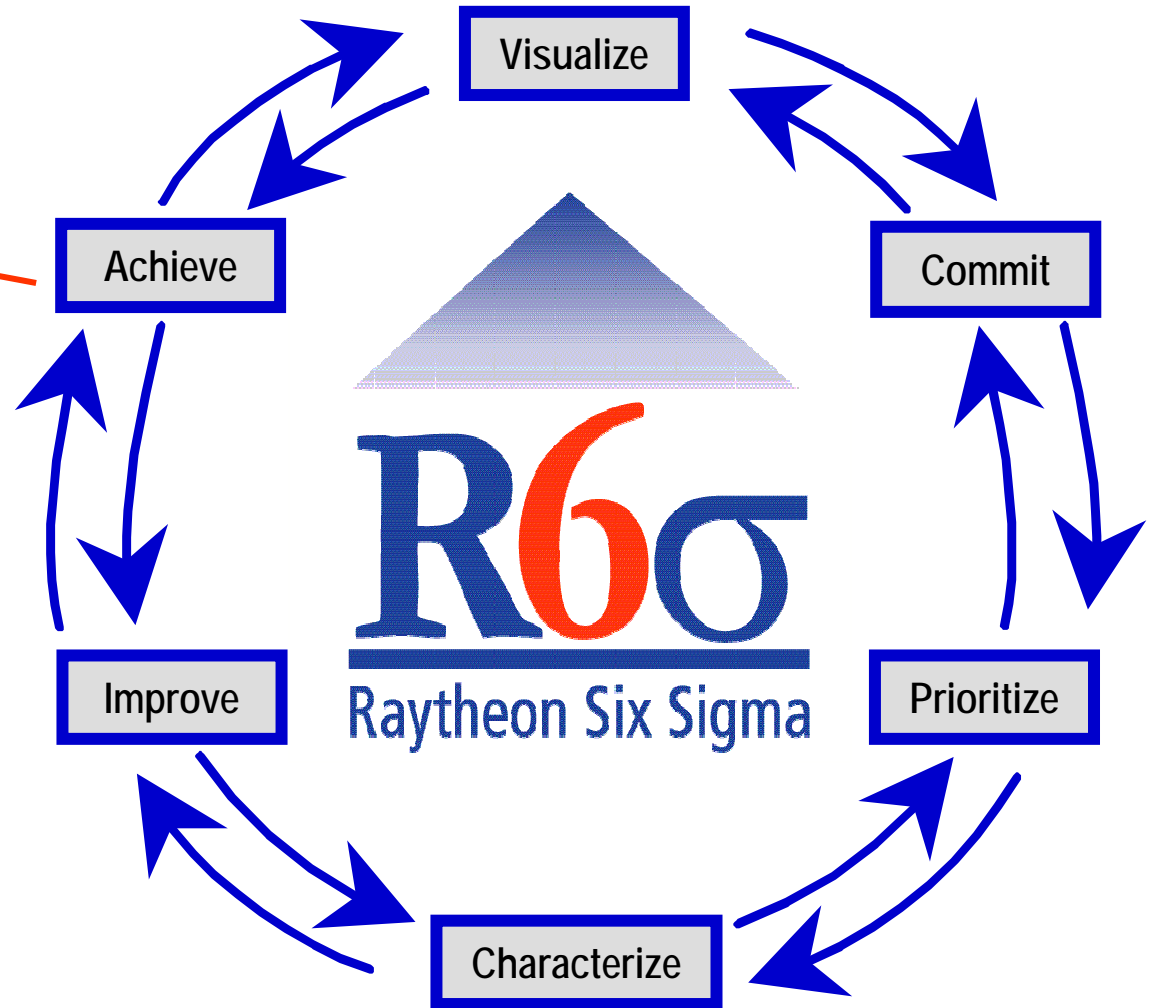
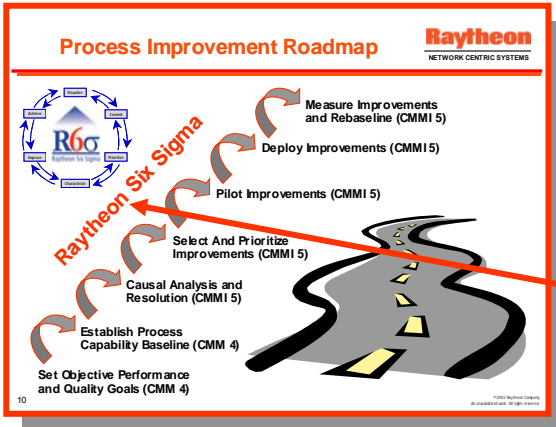
## ■ Organizational Innovation and Deployment

- “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

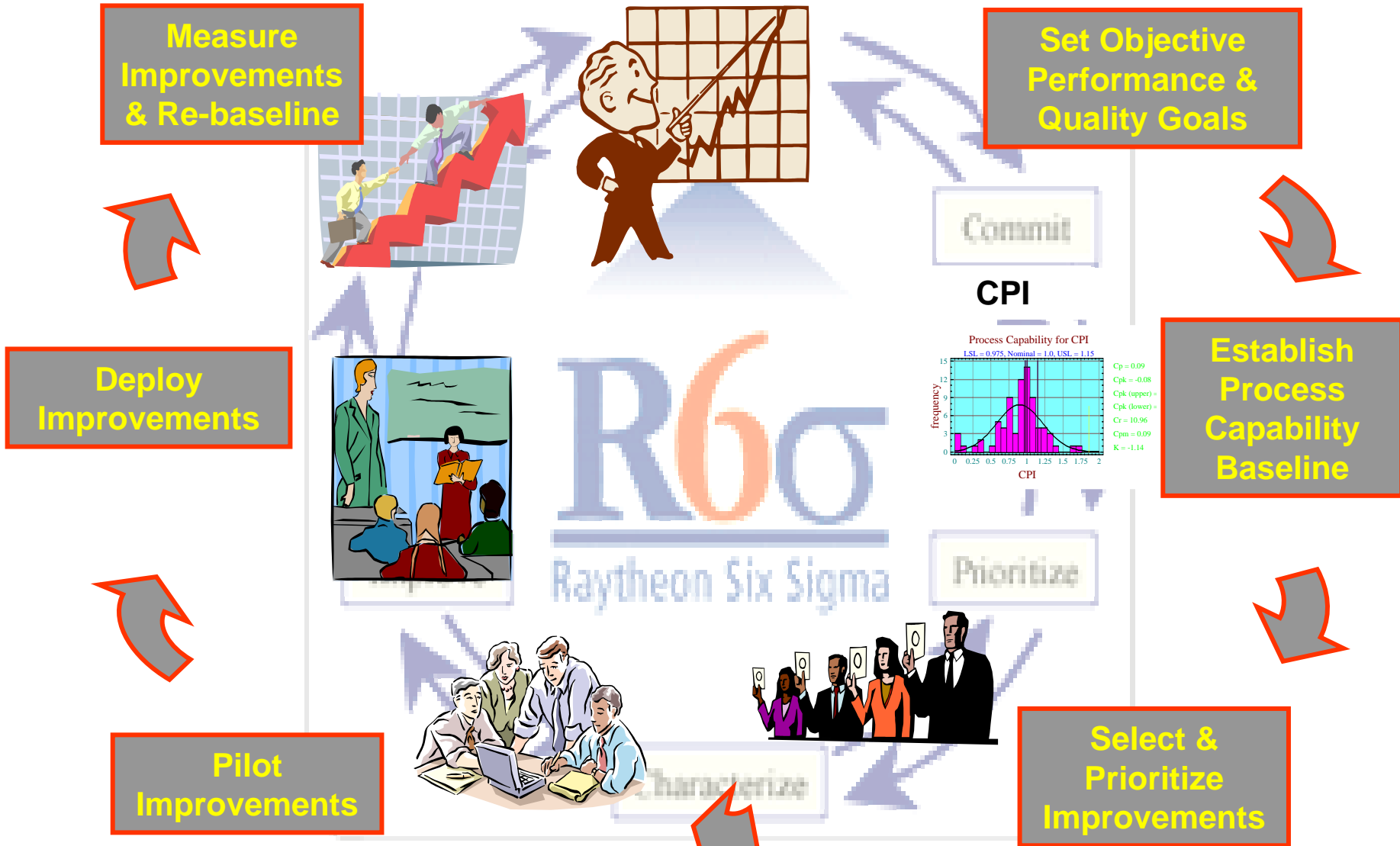
- “The purpose of Causal Analysis and Resolution is to identify causes of defects and other problems and take action to prevent them from occurring in the future” - CMMI SE/SW v 1.1
- FSCS performed causal analysis as part of monthly metrics analysis activities and identified resolutions as improvement action plans

# Raytheon Six Sigma Foundation



**Raytheon Six Sigma  
was used to Achieve  
Continuous  
Improvement**

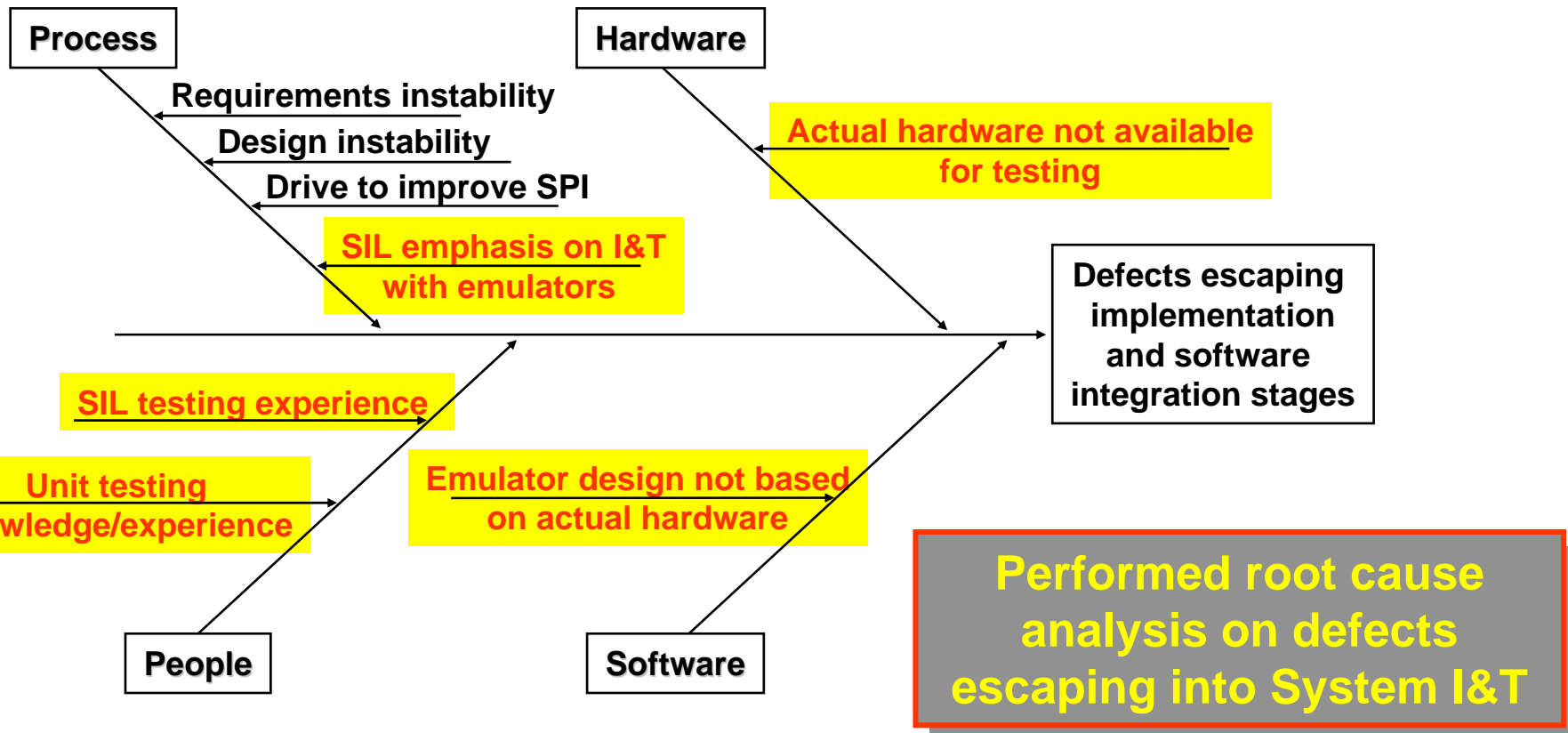
# R6σ Maps to CMMI Level 5



## **Act Three**

# **Achieving Continuous Improvement on FSCS**

- The FSCS Metrics Analysis process included detailed analysis of the defect metrics to determine root cause





- **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

- **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

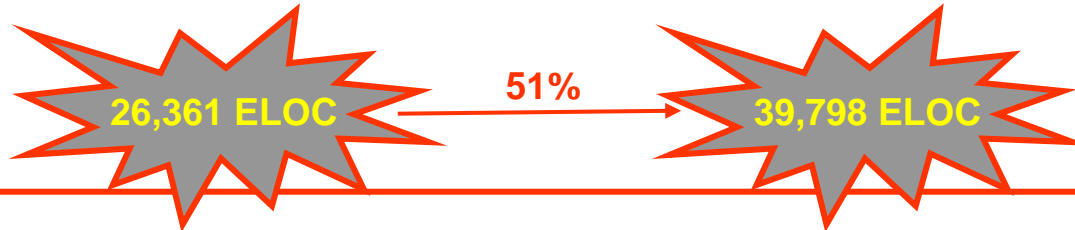
JUL 2001 Cum CPI / SPI = .91 / .93

JAN 2002 Cum CPI / SPI = .96 / .99

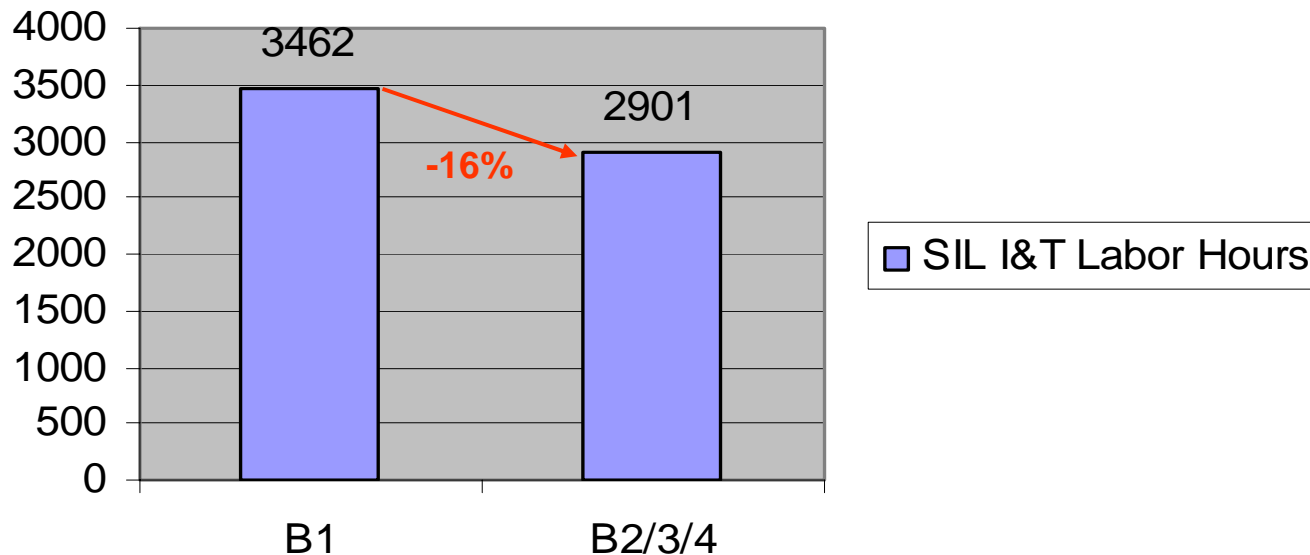
— 5% / 6% improvement

**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**



**16% fewer hours were used to integrate 51% more ELOC (including regression test)**

# Comparison of B1 and B2/3/4 Metrics

Tracer Build 1 Defect Containment									
Stage	Stage Originated								Totals
Detected	RA	SD	OD	IM	SIL	SIT	AT	Maint	
RA	19								19
SD	10	20							30
OD	8	1	141						150
IM	1	0	3	113					117
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SIT	1	1	6	57	2	21			88
AT	0	0	0	0	0	0	0		0
Maint	0	0	0	0	0	0	0	0	0
Totals	39	22	151	184	36	21	0	0	453
Goal									
Detected In Stage:			348	77%	Detected In Stage:			>80%	
Total Escaped:			105	23%	Total Escaped:			<20%	

26,361 ELOC

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

Tracer Build 2 Defect Containment									
Stage	Stage Originated								Totals
Detected	RA	SD	OD	IM	SIL	SIT	AT	Maint	
RA	12								12
SD	0	8							8
OD	0	0	197						197
IM	0	1	2	201					204
SIL	0	0	8	60	5				73
SIT	0	1	3	26	3	15			48
AT	0	0	0	0	0	0	0		0
Maint	0	0	0	0	0	0	0	0	0
Totals	12	10	210	287	8	15	0	0	542
Goal									
Detected In Stage:			438	81%	Detected In Stage:			>80%	
Total Escaped:			104	19%	Total Escaped:			<20%	

19,869 ELOC

In Range!

# Comparison of B1 and B2/3/4 Metrics

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Totals	39	22	151	184	36	21	0	0	453
Goal									
Detected In Stage:			348	77%	Detected In Stage:			>80%	
Total Escaped:			105	23%	Total Escaped:			<20%	

**26,361 ELOC**

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

Tracer Build 2 Defect Containment									
Stage Detected	Stage Originated								Totals
	RA	SD	OD	IM	SIL	SIT	AT	Maint	
RA	12								12
SD	0	8							8
OD	0	0	197						197
IM	0	1	2	201					204
SIL	0	0	8	60	5				73
SIT	0	1	3	26	3	15			48
AT	0	0	0	0	0	0	0		0
Maint	0	0	0	0	0	0	0	0	0
Totals	12	10	210	287	8	15	0	0	542
Goal									
Detected In Stage:			438	81%	Detected In Stage:			>80%	
Total Escaped:			104	19%	Total Escaped:			<20%	

**19,869 ELOC**

**In Range!**

- **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%**



# CMMI Level 5 Practices

Measure Improvements & Re-baseline

Results

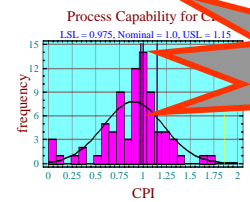


Set Objective Performance & Quality Goals

QPM Plan

Stabilize process & Establish Process capability Baseline

CPI



Metrics Analysis

Deploy Improvements

EEOS B2  
VMSS, B3/4



R6σ  
Raytheon Six Sigma

Prioritize

Select & Prioritize Improvements

InfoDev B2

Pilot Improvements



Characterize



New Unit Test JITT, new SIL I&T JITT

- **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

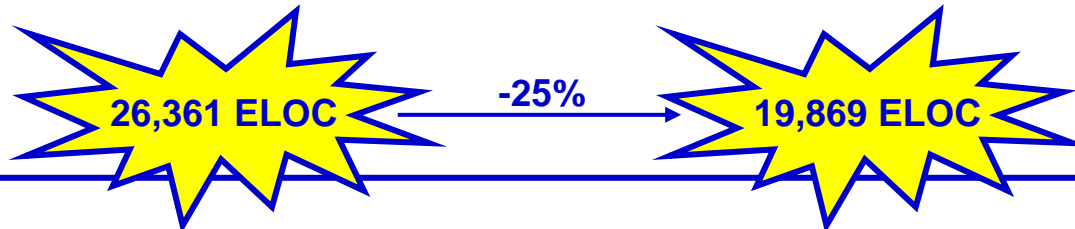
## ■ In Stage Defects

$$\frac{\left| 117 - \frac{204}{\left[ 1 - \frac{(26,361-19,869)}{26,361} \right]} \right|}{117} = 132\%$$

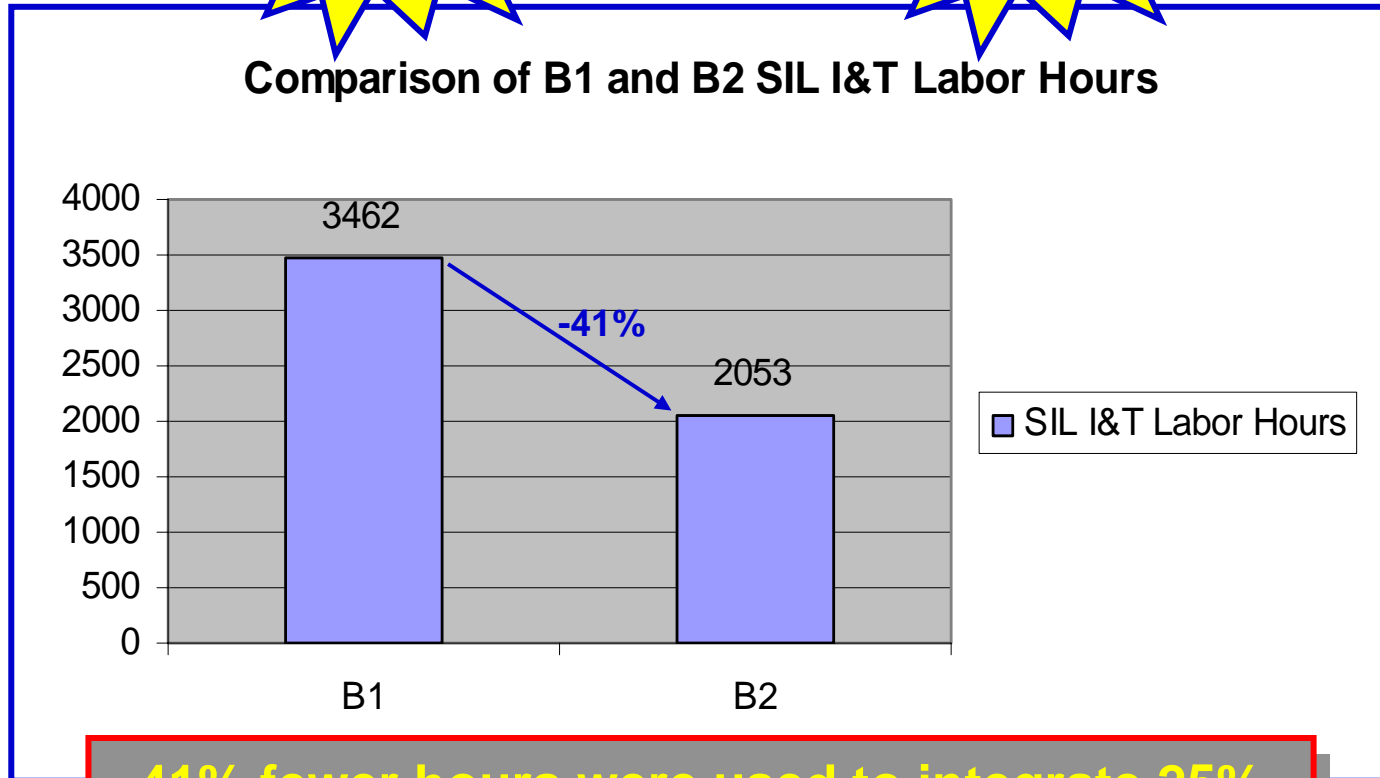
## ■ Out of Stage Defects

$$\frac{57 - \frac{26}{\left[ 1 - \frac{(26,361-19,869)}{26,361} \right]}}{57} = 39\%$$

# Comparison of B1 and B2/3/4 Metrics



Comparison of B1 and B2 SIL I&T Labor Hours



**41% fewer hours were used to integrate 25% less ELOC (including regression test)**

# CMMI Level 5 Behavior Context Diagram

