Raytheon

Customer Success Is Our Mission

5 Major Sites,
4 Separate Disciplines,
5,221 Engineers,
1 Data Repository:
Having data you can
actually use – Priceless!

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- # Introduction to Raytheon

- # Measurement-related Goals

- # Measurement Process Overview

- # Best Practices

  - Measurement Definition

  - Measurement Collection

  - Measurement Analysis

  - Tooling/Automation

- # Future Opportunities

- # Results

- # Q & A

Raytheon and NCS

- Raytheon is an industry leader in defense and government electronics, space, information technology, and technical services

- Network Centric Systems (NCS) develops and produces mission solutions for networking, command and control, battle space awareness, homeland security and air traffic management

tes and Overall Goal

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> **NCS Goal:**
> **Achieve NCS**
> **CMMI Level 5**
> **for SE, SW,**
> **and HW**

Marlborough, MA

Ft. Wayne, IN

Fullerton, CA

McKinney, TX

St. Petersburg, FL

- ˝ NCS Engineering Organization = Over 5,000 individuals
- ˝ Number of programs to appraise = 33 (CA 8, TX 4, IN 9 , FL 4, MA 8)
- ˝ Various levels of CMMI maturity at the project onset

...mprovement Journey:
# ...Related Goals

- **Establishing a Common Measurement Program**
  - All major NCS sites and engineering disciplines
  - Common plans and work instructions that support CMMI Level 5
  - Common process and tooling

- **Consistent Approach**
  - Define core set of engineering measures
  - Define analysis that should occur at various levels
  - Define measures roll-up as related to NCS goals
  - Define a set of CMMI Level 4 Sub-process approaches

- **Have a "one company" look to our customers**
  - Accurate historical data and consistent estimates across sites
  - Support Mission System Integrator (MSI) role
 - Support multi-site bids and work transfers between sites

Process Overview
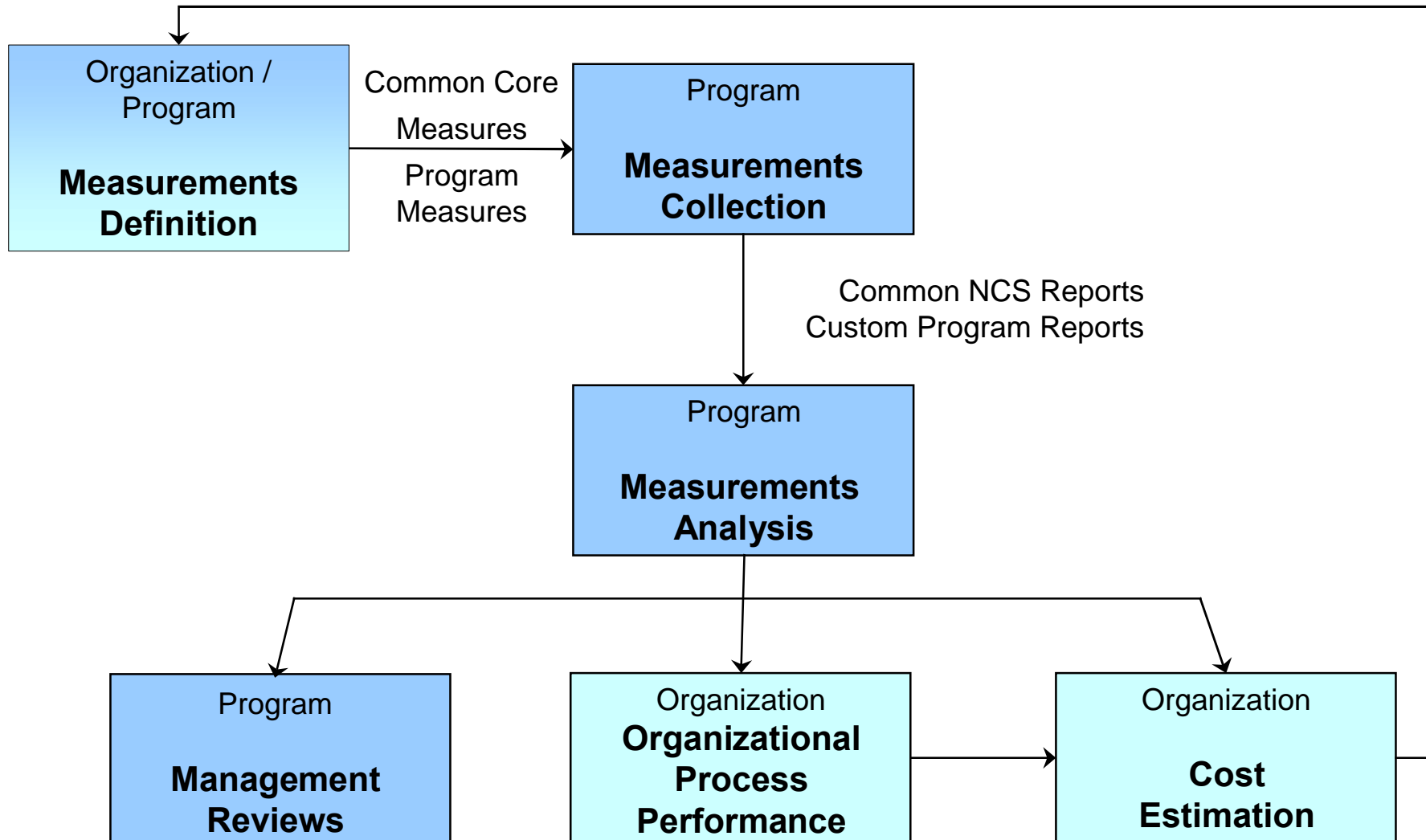
Definition: ...ng Measures

- Cost and Schedule Measures
- Defect Containment
- Staffing Profile
- Measurement Compliance
- Change Management
- Peer Review
- Requirements Volatility
- Design Margin Index (DMI)
- Size
- Productivity

There were many more measures, but Engineering started with a list of core measures
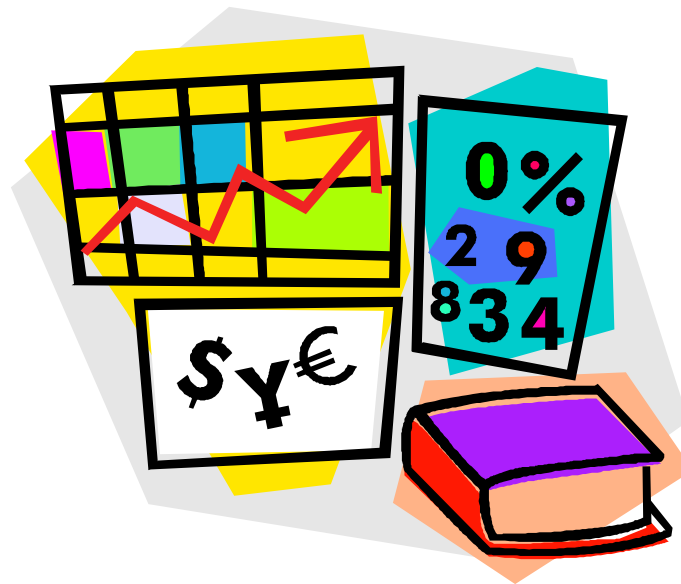
Definition: Cost Collection Scheme

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ACTIVITY TITLE	PE	SE	SW	HW				
				General Hardware	Analog	Digital	FPGA	Mechanical
PROJECT PLANNING & MANAGEMENT								
Planning and Management	✓	✓	✓	✓				
Quality Engineering	✓	✓	✓	✓				
Configuration Management	✓	✓	✓	✓				
REQUIREMENTS DEVELOPMENT								
System Requirements Definition		✓						
System Design & Architecture		✓						
Product Requirements Definition		✓		✓				
Product Design & Architecture		✓		✓				
Component Requirements Definition		✓	✓	✓	✓	✓	✓	✓
PRODUCT DESIGN & DEVELOPMENT								
Requirements Management		✓						
Simulation and Modeling								
Preliminary Design			✓		✓	✓	✓	✓
Detailed Design			✓		✓	✓	✓	✓
Implementation			✓		✓	✓	✓	✓
Integration			✓		✓	✓	✓	✓
SYSTEM INTEGRATION & VALIDATION								
Product Verification & Validation		✓	✓	✓				
System Integration		✓	✓	✓				
System Acceptance Test		✓						
System Field Test		✓						

- Aligns disciplines and activities
- Used to identify and collect costs for Work Breakdown Structure (WBS) elements
- Scheme is aligned with Cost Estimation
- Facilitates collection of consistent historical data
- Defect data can be collected in these bins

Sets the foundation for CMMI Level 5 by aligning cost, schedule, and quality data

Definition:
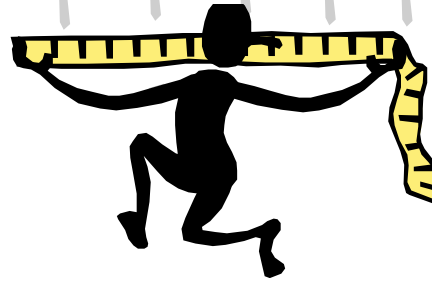# ...res have Consistent Elements

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- Size measures were defined for Systems Engineering (SE), Software (SW), Hardware (HW)-Electrical, HW-FPGA (Field-Programmable Gate Array), and HW-Mechanical disciplines

- Sizes for each discipline were defined to have the capability to be converted to equivalent size units, where equivalent means equivalent to requiring the same amount of effort as developing it from scratch

- Each discipline's size data includes these elements
  - **Reused**
  - **Modified**
  - **New**
  - **Reuse Factor (F_R)**
  - **Modified Factor (F_M)**

Equivalent = New + (Modified * F_M) + (Reused * F_R)

Definition:
Measures with CO SYS MO
CONSTRUCTIVE SYSTEMS ENGINEERING COST MODEL

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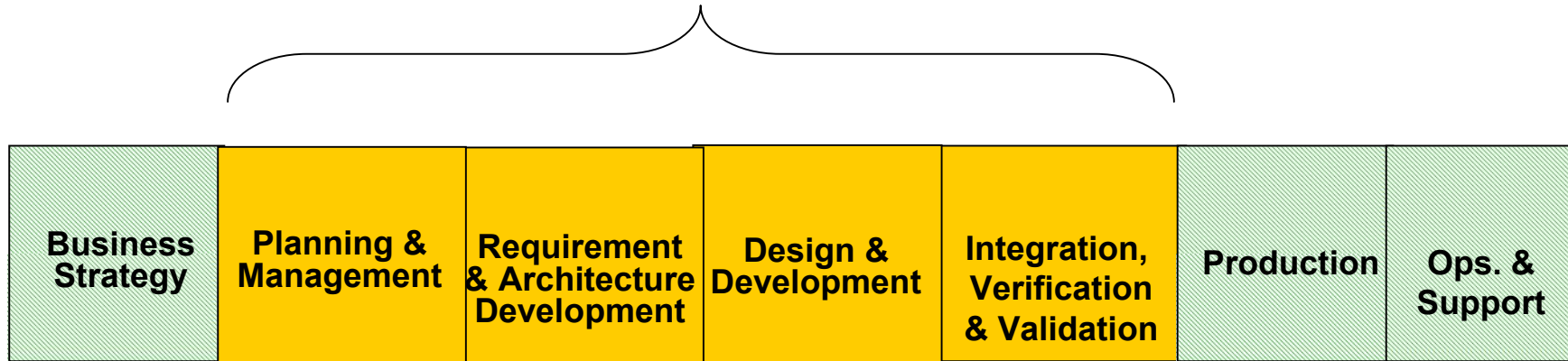
- Raytheon created the SECOST tool, which aids deployment and company calibration with the Constructive Systems Engineering Cost Model (COSYSMO)
- NCS System Engineering sizes are aligned with COSYSMO sizes
- For each system of interest these are collected to compute equivalent requirements (EREQ):
  - System requirements
  - System interfaces
  - System algorithms
  - System scenarios
- For a complete SE size set of requirements data, additional NCS SE size measures include:
  - Software product requirements
  - Hardware product requirements
  - Hardware component requirements

Definition: ...ductivity Activities

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SE Full Life Cycle Productivity

Business Strategy	Planning & Management	Requirement & Architecture Development	Design & Development	Integration, Verification & Validation	Production	Ops. & Support

SE Specific Life Cycle Stage Productivities
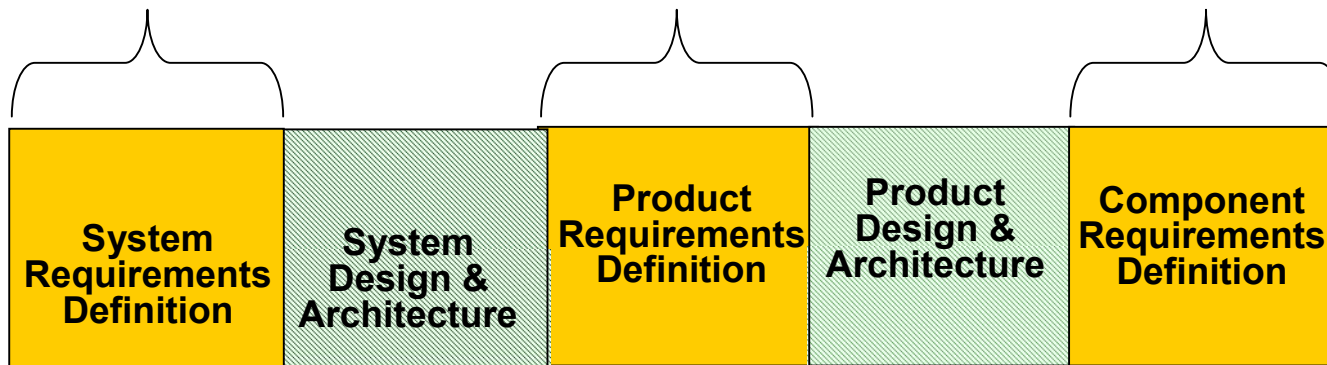
System Requirements Definition	System Design & Architecture	Product Requirements Definition	Product Design & Architecture	Component Requirements Definition

Specific cost collection codes are used to capture hours for Productivity measures

Definition: Measures with Cost Models

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- Raytheon has used parametric SW models such as COCOMO, COCOMO II, REVIC, Price-S, and SEER-SEM for many years

- Specific alignment was made to the SEER-SEM SW Application types to allow stratification of data such as productivity

- NCS SW Size measures support these models with parameters of Source Lines of Code (SLOC) categorized by Reused, Modified, and New, with Reuse and Modified Factors

- A standard NCS software line counting tool was deployed across all sites so that sizes are measured consistently and with automation
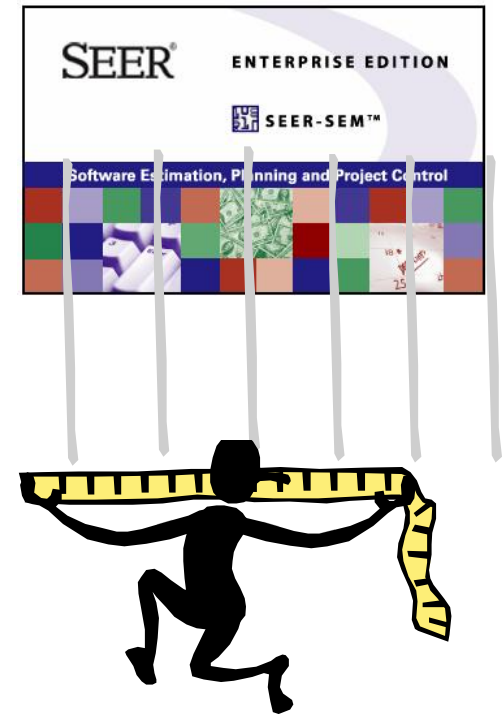
Definition: ...oductivity Activities

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SW Development Productivity Stages
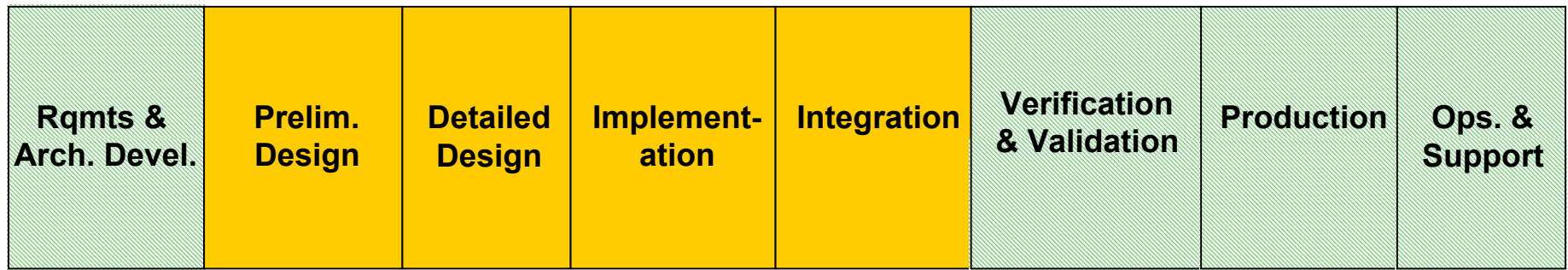
Rqmts & Arch. Devel.	Prelim. Design	Detailed Design	Implement-ation	Integration	Verification & Validation	Production	Ops. & Support

Specific cost collection codes are used to capture hours for Productivity measures

Definition:
...res

HW Sub-Discipline	Size Unit	Definition of Size Unit
Electrical	Terminations	Termination count is the sum of all external physical leads
FPGA	FPGA Lines of Code	Lines of Code - like software engineering
Mechanical	Square Feet of Drawing	The square feet of drawings required to document the design
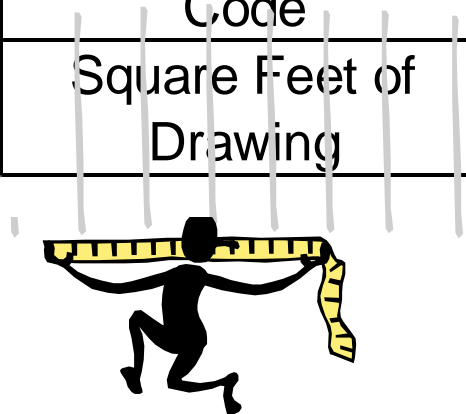
Hardware Size Units are an indication of which hardware sub-discipline is producing this data

Definition:
...oductivity Activities

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**HW Development
Productivity Stages**

Reqs & Architecture Devel.	Prelim. Design	Detailed Design	Implement-ation	Integration	Verification & Validation	Production	Ops. & Support
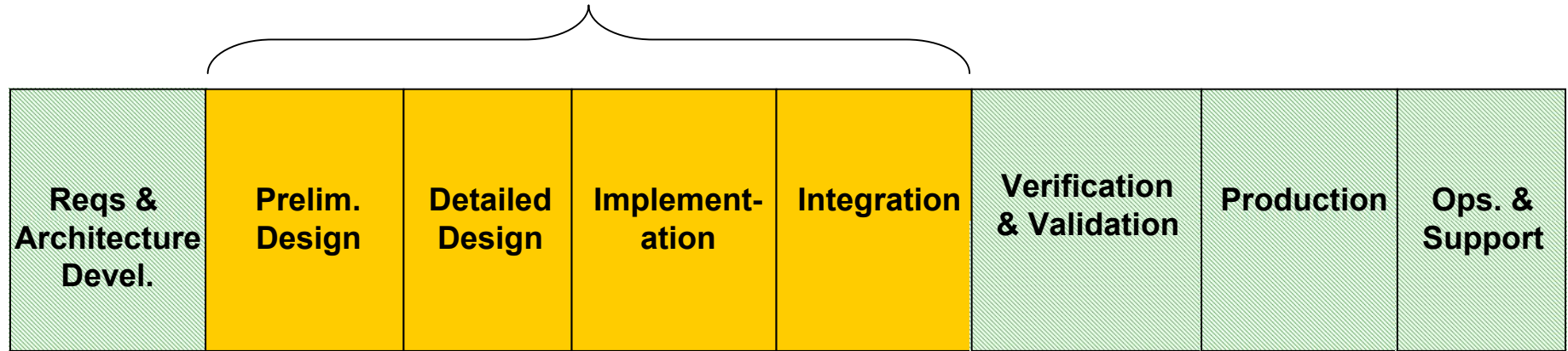
Collected separately for:
- ″ **Electrical**
- ″ **FPGA, and**
- ″ **Mechanical**

Quantitative Analysis: Program Activities

MTBF . Mean Time Between Failures
AUPC . Average Unit Production Cost
DPMO . Defective Parts per Million Opportunities
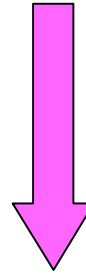
CPI	SPI	Defect Containment	Productivity

↓

Standard Process, Tools, Enablers, Technology

Inspection Calculator:
Peer Review Defect Density
Review / Development Stage

Price-H:
AUPC
Design for Cost

ASENT/Block SIM:
MTBF
Requirements Analysis/
Design for Reliability

Legend
" Tool
" Measure
" Sub-process

PCAT:
Cost, DPMO
Design for Cost /
Design for Producibility

SECOST:
Effort hours by stage
Development Stage

Programs have a variety of tools and models to use for statistical control

- Analysis: Baselines - Peer Review Example

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Program Execute Peer Reviews

Programs select baselines, use control charts, and analyze capability monthly

Programs record Peer Review data in review tools

Measurement Repository

Establish Org Baselines

Program Baseline

Org Baseline

iMetrics DB

SE

SW

"
"

HW
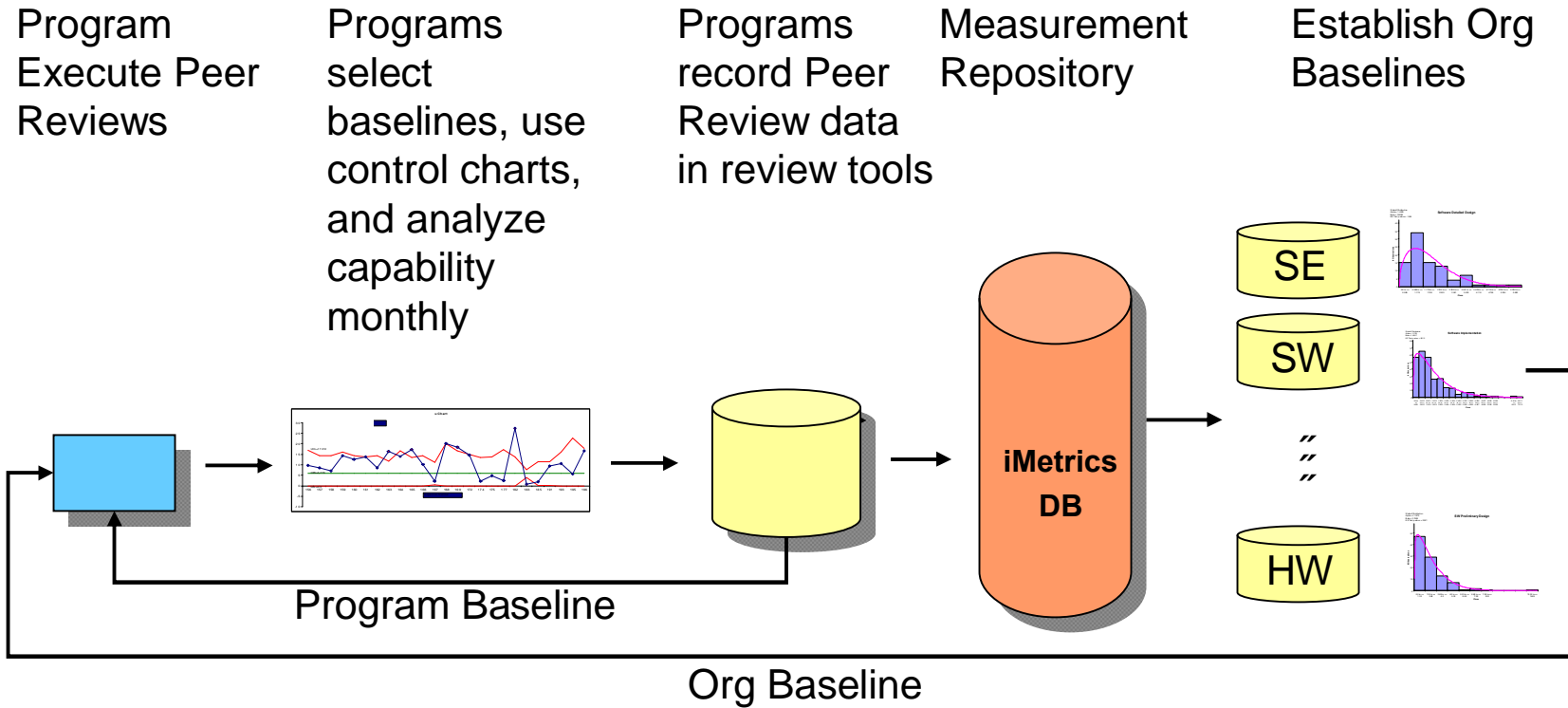
- **Programs use latest org baselines and program/product line baselines**
- **Baselines are recalculated periodically and then fed back to programs**
- **Peer review tools are updated to include new org norms**

Analysis:
to Architecture

KPP - Key Performance Parameters are system level attributes

TPM - Technical Performance Measures are functions of Key Product Characteristics

KPC . Key Product Characteristics can significantly affect a TPM or KPP
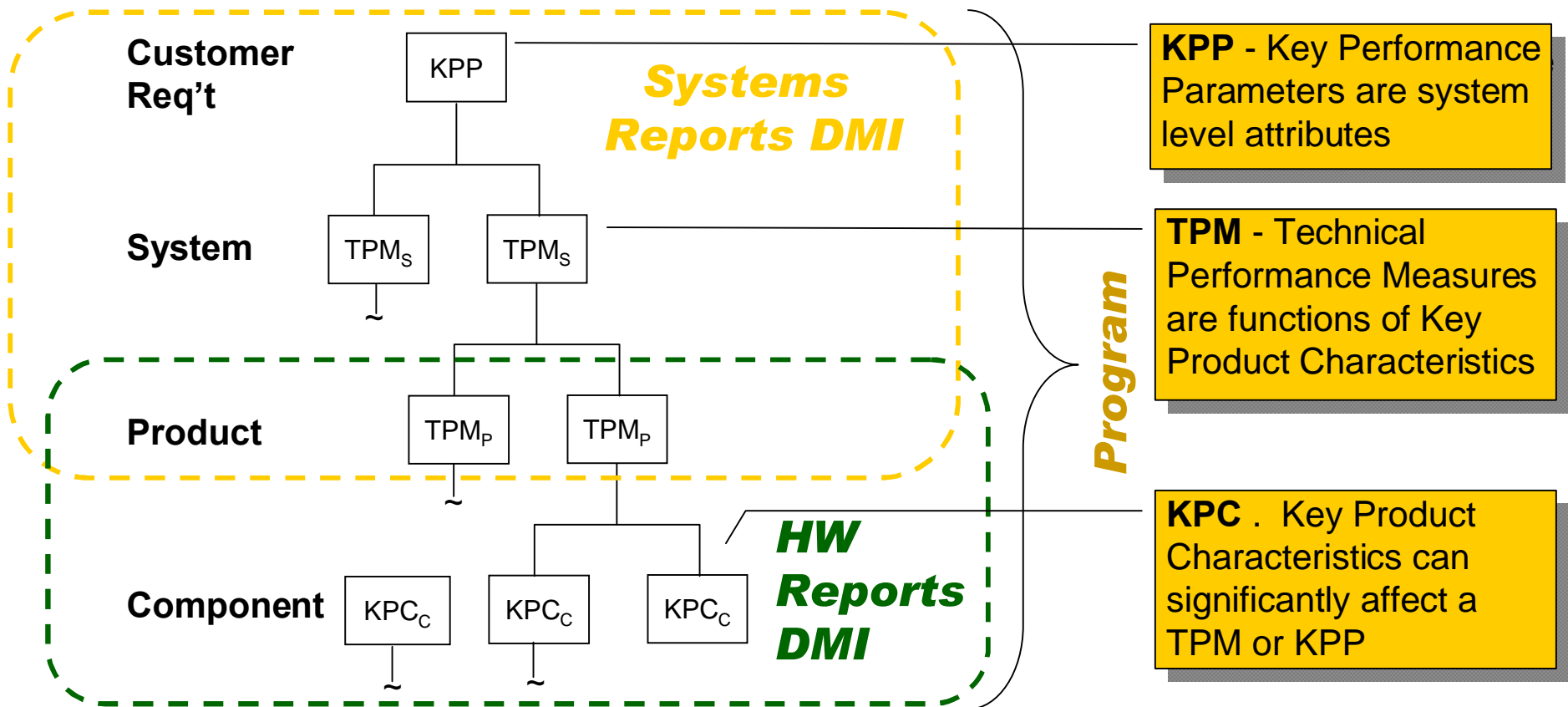
- **KPPs are decomposed into objectives and managed at lower levels to ensure program success**
- **DMI is an <u>index</u> used to measure the <u>design margin</u>**
- **DMI is a useful measure for assessing "over" design and "under" design**

Analysis: over Program Life Cycle

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Requirements Decomposition		Requirements Definition		Design	Mfg/Test
		Form, Fit, or Functional Limit(s)	Allocate "Cpk Target" (Cpk_T)	Predict "Current Cpk" (Cpk_P)	Measure "Actual Cpk" (Cpk_M)

Customer Requirement — KPP

System — TPM_S, TPM_S ~

Product (i.e. Line replac-able units, Subsystems, Etc.) — TPM_P, TPM_P ~

Component (i.e. Circuit Cards, Cables, etc.) — KPC_C, KPC_C, KPC_C ~

Allocate DM

Row values: Cpk_T (Customer Requirement), Cpk_T (System), Cpk_T (Product), Cpk_T (Component)

USL, LSL, σ_P, μ_P, σ_M, μ_M

- ▪ **TPMs are used for quantitative management and statistical control**
- ▪ **This gives the programs added value and can help significantly reduce program costs**

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Program Engineer and Discipline Teams

NCS Engineering Process Steering Team

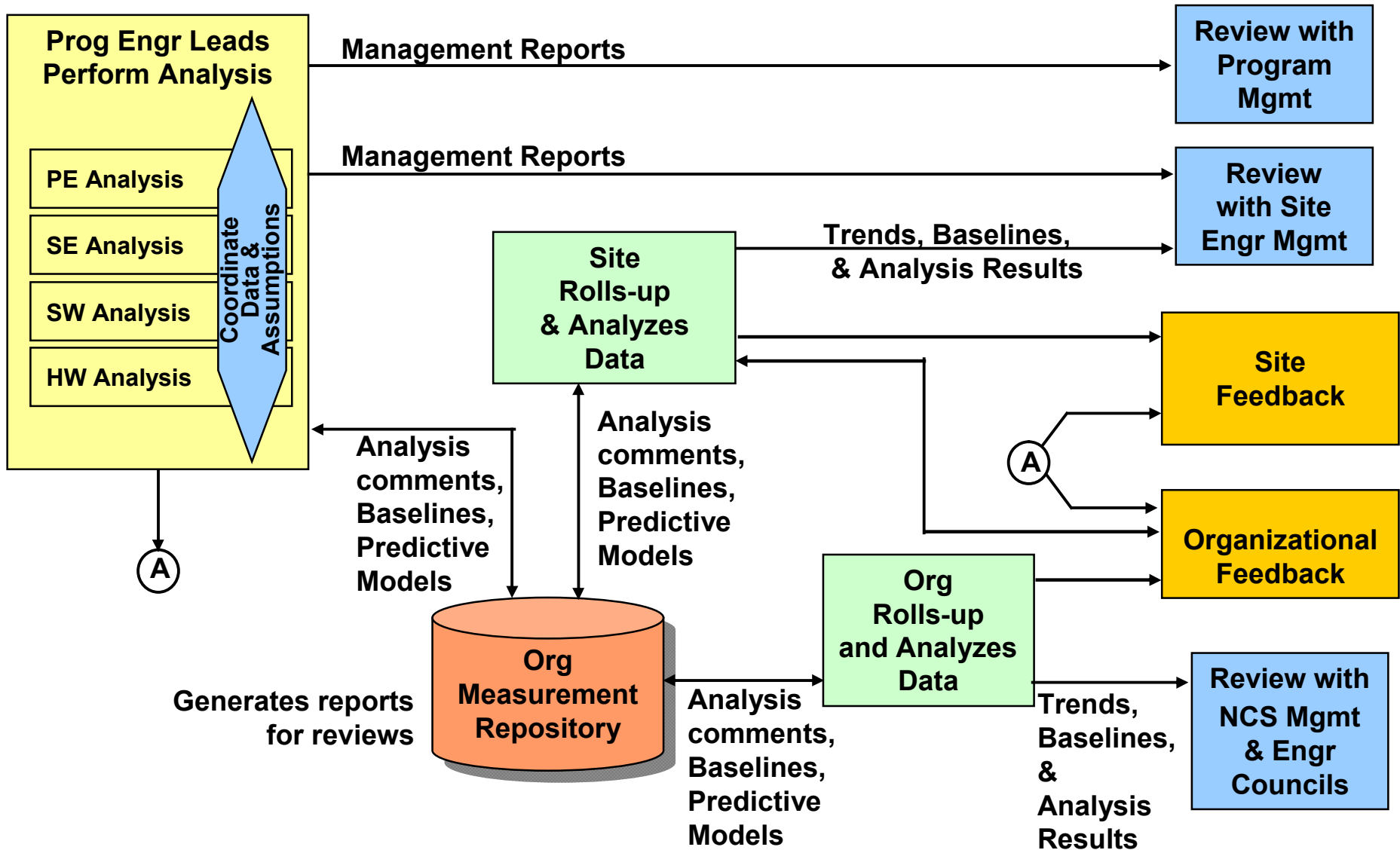Engineering Councils

NCS Measurement Council
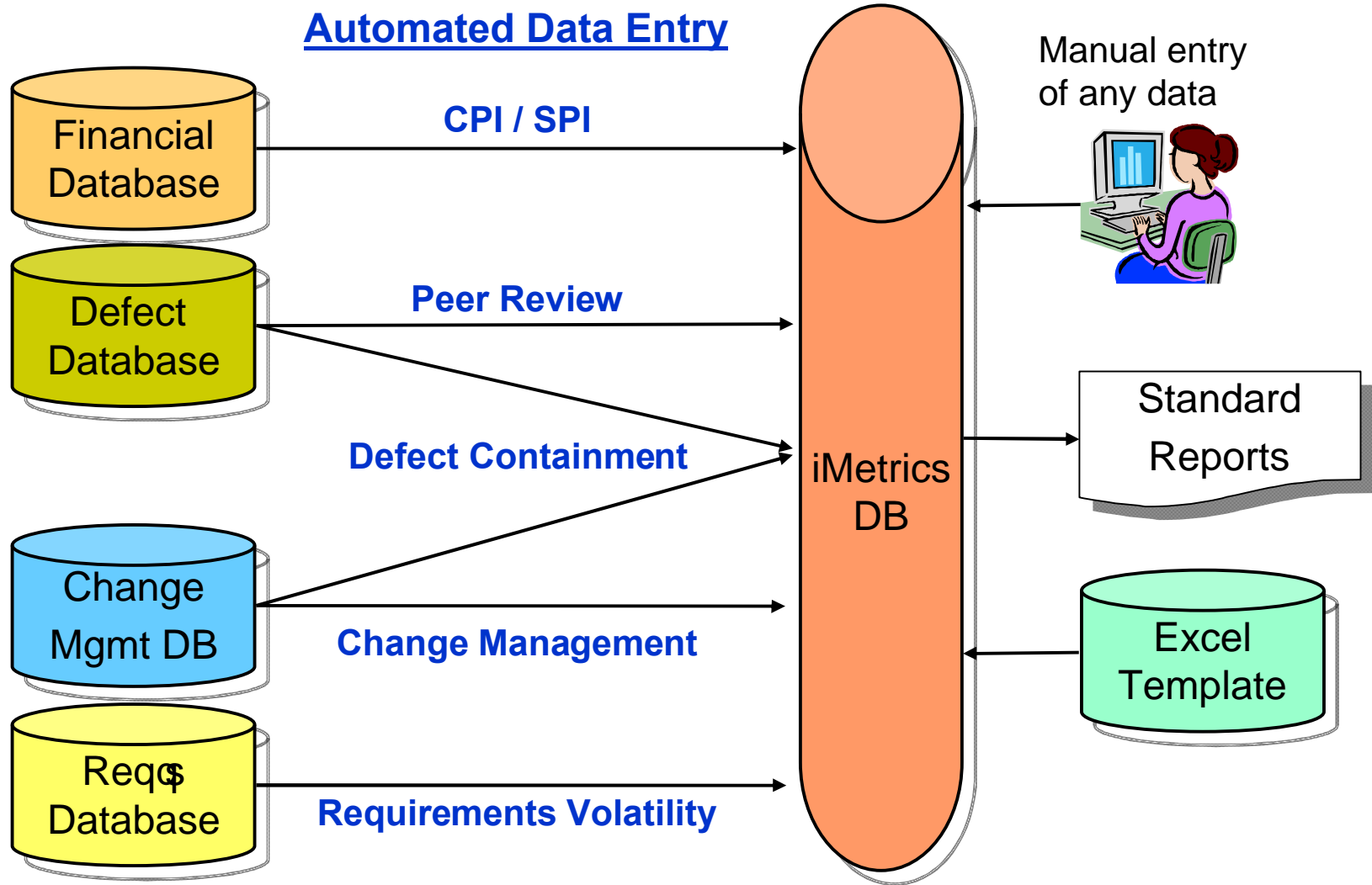

Site Measurement Teams

Engineering Management

- High level teams and managers were very interested is analyzing and reviewing measurement data
- This created a positive "pull" for information across NCS

Analysis & Review: s and Review Flow

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Prog Engr Leads Perform Analysis

- PE Analysis
- SE Analysis
- SW Analysis
- HW Analysis

Coordinate Data & Assumptions

Management Reports → **Review with Program Mgmt**

Management Reports → **Review with Site Engr Mgmt**

Site Rolls-up & Analyzes Data

Trends, Baselines, & Analysis Results → Review with Site Engr Mgmt

→ **Site Feedback**

A

→ **Organizational Feedback**

Analysis comments, Baselines, Predictive Models

Analysis comments, Baselines, Predictive Models

A

Generates reports for reviews

Org Measurement Repository

Analysis comments, Baselines, Predictive Models

Org Rolls-up and Analyzes Data

→ **Organizational Feedback**

Trends, Baselines, & Analysis Results → **Review with NCS Mgmt & Engr Councils**

Consistent flow across NCS sites and disciplines

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Tooling:
...omate Databases and Tools

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Automated Data Entry

Financial Database — **CPI / SPI** → iMetrics DB

Defect Database — **Peer Review** →

Defect Containment →

Change Mgmt DB — **Change Management** →

Reqts Database — **Requirements Volatility** →

Manual entry of any data →

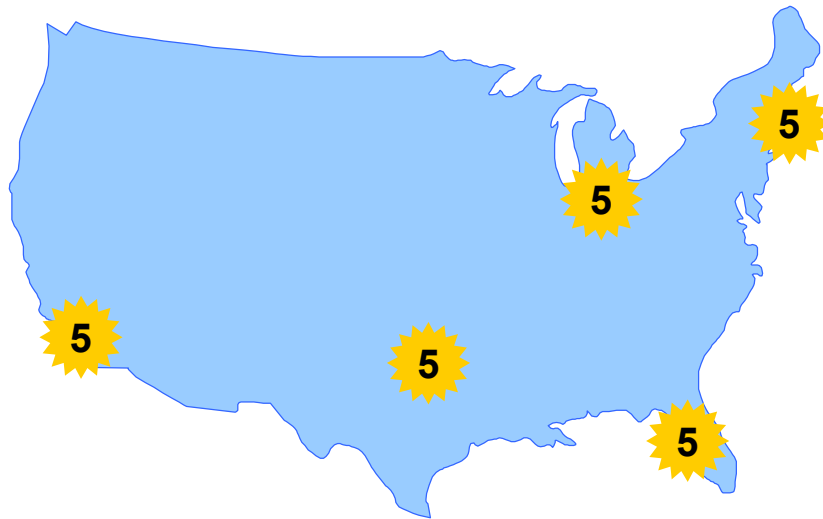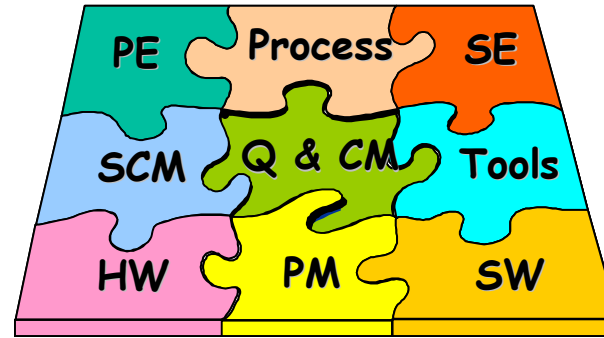Standard Reports

Excel Template →

Automation allows repeatable quick entry of data tools to supply measurement data!

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...unities

- Increase the coverage and use of common cost collection codes to more disciplines and activities

- Extend use of measurement database to other roll-up management measures such as Oregon Productivity Matrixes (OPMs)

- Incorporate statistical and textual analysis capability into the measurement reporting automation

- Improve alignment of financial processes and tooling with the common cost collection codes

- Define collection scheme for the Incremental Development life cycle model

- Continue to broaden the scope of automation that supports collection and reporting or measures

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Raytheon NCS deploys integrated processes with measures across multiple disciplines and sites to an engineering org of over 5,000 !!!

CMMI Level 5

Cooliemon, LLC
completed a
Capability Maturity Model Integration (CMMI®) Appraisal
On 6/1/2007
According to the Software Engineering Institute (SEI)
Standard CMMI® Appraisal Method for Process Improvement v1.1
SCAMPI^{SM} - Class A
and rated

Raytheon Network Centric Systems
(SE/SW/HW)
a
CMMI® Maturity Level 5

Ralph Williams
SEI Authorized Lead Appraiser
ID 01000073-00

Raytheon NCS Achieves CMMI Level 5 on 1 June 2007 for Systems, Software, and Hardware Engineering !

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QUESTIONS ?

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