

Ogden Air Logistics Center



U.S. AIR FORCE



Reliability Index for the USMC Expeditionary Fighting Vehicle

SSTC 2008 – 1 May 2008

**Robert J. Knapper
David L. Jolley
David R. Webb**



Outline



OGDEN AIR LOGISTICS CENTER

- Expeditionary Fighting Vehicle
- Traditional Reliability Measures
- Why Software is Different
- Full-Lifecycle Software Reliability Measurement
- 309th SMXG
- Software Reliability Issues
- TSP Process Quality Index
- Software Reliability Index
- Pros and Cons
- Conclusions
- Contact Information



Expeditionary Fighting Vehicle Overview



OGDEN AIR LOGISTICS CENTER

- **USMC Expeditionary Fighting Vehicle (EFV)**
 - Armored amphibious vehicle capable of seamlessly transporting Marines from Naval ships located beyond the visual horizon to inland objectives
 - Primary means of tactical mobility for the Marine Rifle Squad during the conduct of amphibious operations and subsequent ground combat operations ashore.
 - Keystone for both the Marine Corps Expeditionary Maneuver Warfare and Ship-to-Objective Maneuver warfighting concepts
- **EFV PMO – Program Manager, Advanced Amphibious Assault**
- **Prime Contractor – General Dynamics Amphibious Systems**
- **Status**
 - **Currently in the System Development and Demonstration (SDD) Acquisition Phase**
 - **Operational Assessment in FY 2011**
 - **Low-Rate Initial Production Scheduled for FY 2012**



Expeditionary Fighting Vehicle Mission Capabilities



OGDEN AIR LOGISTICS CENTER



Move - Land



Carry



Move - Water



Shoot



Communicate



Expeditionary Fighting Vehicle Characteristics



OGDEN AIR LOGISTICS CENTER

■ General

- Amphibious Tracked Vehicle
- “Drive-by-wire”
- Land mobility at 45mph on par with M1 Abrams Tank
- Water mobility from over the horizon to shore at 25kts
- Armed and armored to engage and protect
- Net-ready

■ Personnel Variant

- Carries Marine Rifle Squad for conduct of amphibious operations and subsequent ground combat operations ashore
- Incorporates MK46 Weapon System
 - MK44 30mm High Velocity Cannon and 7.62mm Coax Machine Gun
 - Fully Stabilized with Digital Fire Control and Thermal Sight for all-weather / all-night lethality

■ Command Variant

- Carries C2 systems and Operators
- Provides Situational Awareness at the Squad Level
- Provides Command and Control at the Battalion/Regimental Level.



Expeditionary Fighting Vehicle Software



OGDEN AIR LOGISTICS CENTER

■ Software Control

- Vehicle Electronics Systems for Mobility, Fire Control, and C2 supported by real-time, embedded software
- GDAMS developed software for first set of SDD EFV prototypes (9 P-Variant, 1 C-Variant)
 - SDD-1 software used for first OA and Design for Reliability Effort following OA
 - Provided valuable feedback for verifying and validating SDD-2 software requirements
- Long-term Program strategy shifted future software development and maintenance to a Government activity
 - 309 SMXG selected for SDD-2 development and follow-on sustainment activity
- Both short-term and long-term reliability measures for 309 SMXG generated SDD-2 software is needed



Traditional Reliability Measures



OGDEN AIR LOGISTICS CENTER

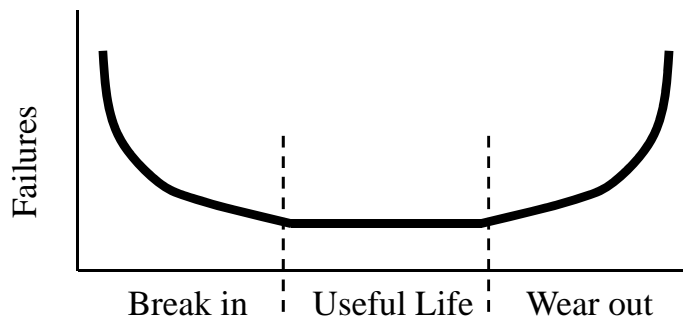
- **Operational Definition of Reliability:**
 - Mean Time to Failure (MTTF) combined with Mean Time to Repair (MTTR) is essentially an availability measure
- **Focus primarily on defect identification and removal**
 - E.g. Rayleigh Model looks at defect density rates over time as well as cumulative defect arrival patterns
 - Incorporated into lifecycle modeling for post-deployment
 - Maintenance cycles
 - Spares
- **Equate Quality with Reliability**
 - Fewer defects means higher reliability
- **Availability Improvement**
 - Mitigate MTTF/MTTR risks with maintenance scheduling and execution tailored to expected failure rates



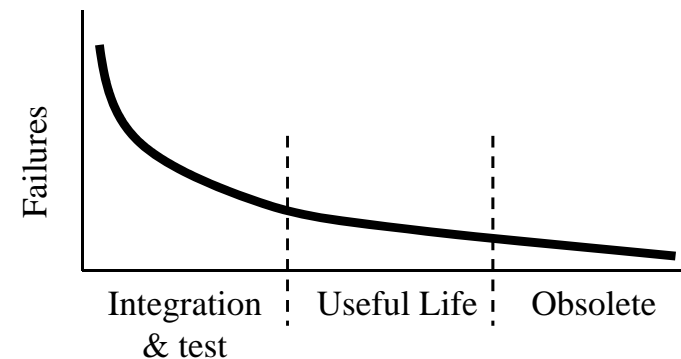
Why Software is Different

OGDEN AIR LOGISTICS CENTER

- Traditional Mean Time to Failure metric does not adequately apply to software
- Software does not “wear out” like hardware
 - Mechanical and electronic components weaken with age.
 - Software does not weaken with age, but over time may become OBE or simply obsolete.



Hardware Failure Rate



Software Failure Rate



Full-Lifecycle Software Reliability Measurement



OGDEN AIR LOGISTICS CENTER

- **Common Software Reliability Measurement**
 - Entire Development Phase
 - Testing Phase
- **Promoting Reliability Improvement**
 - Front-end and back-end phases of the lifecycle are key contributors
- **Need to Measure for Reliability at all phases**
 - Requirements
 - Architecture and Design
 - Coding
 - Integration and Test
 - Deployment
 - Sustainment
- **309 SMXG is Piloting a Full-Lifecycle Software Reliability Measurement activity for EFV**



309th SMXG Hill AFB - Utah



OGDEN AIR LOGISTICS CENTER



HAFB Software Support Facility
Hill Air-Force Base, Utah





309th SMXG Resources

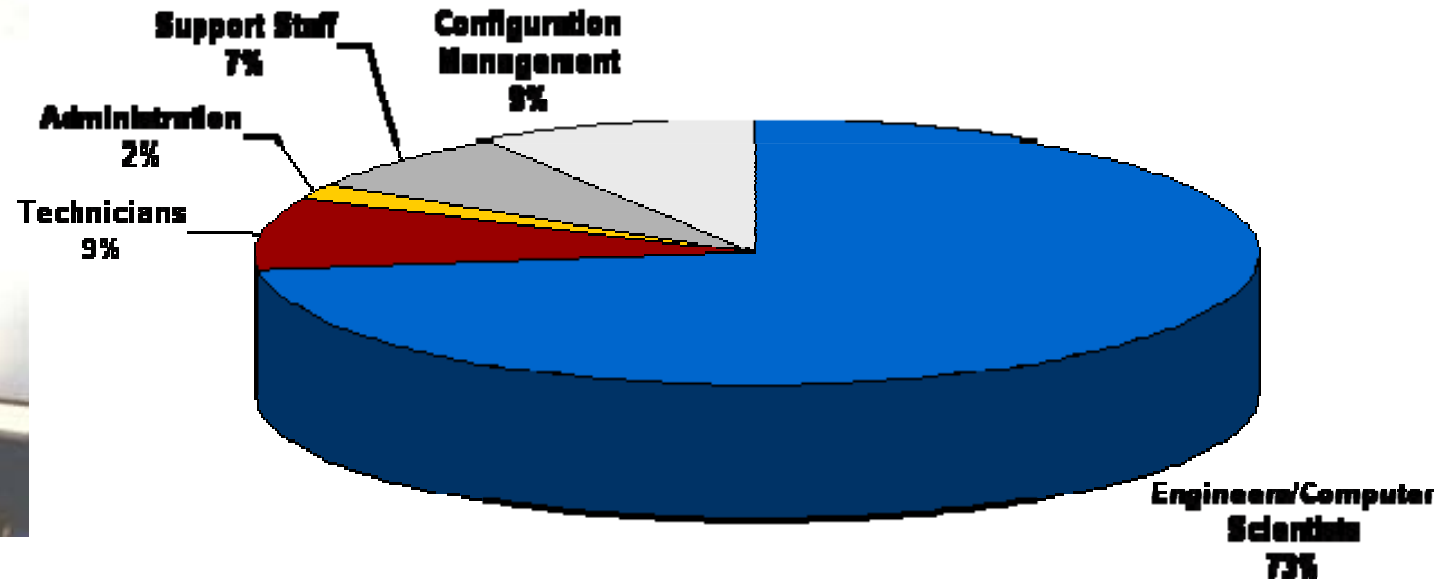


OGDEN AIR LOGISTICS CENTER



Large Cadre of Talented People:

- 800+ Personnel
- Average over 10 years technical experience
- Growing by ~50 PEs/Year





309th SMXG Process Improvement Leader



OGDEN AIR LOGISTICS CENTER

- Focused on process improvement since 1991
- Assessed in 1998 to be Capability Maturity Model (CMM) - Level 5
 - The highest rated level possible
 - First DoD government organization to receive CMM Level 5 rating
- Earned AS9100 & ISO 9001 Registration in 2006
- Assessed in 2006 to be Capability Maturity Model Integration (CMMI) – Level 5
 - Ranks SMXG in top 4% of all organic software organizations
 - Only government organization continuously rated CMM/CMMI level 5 since 1998



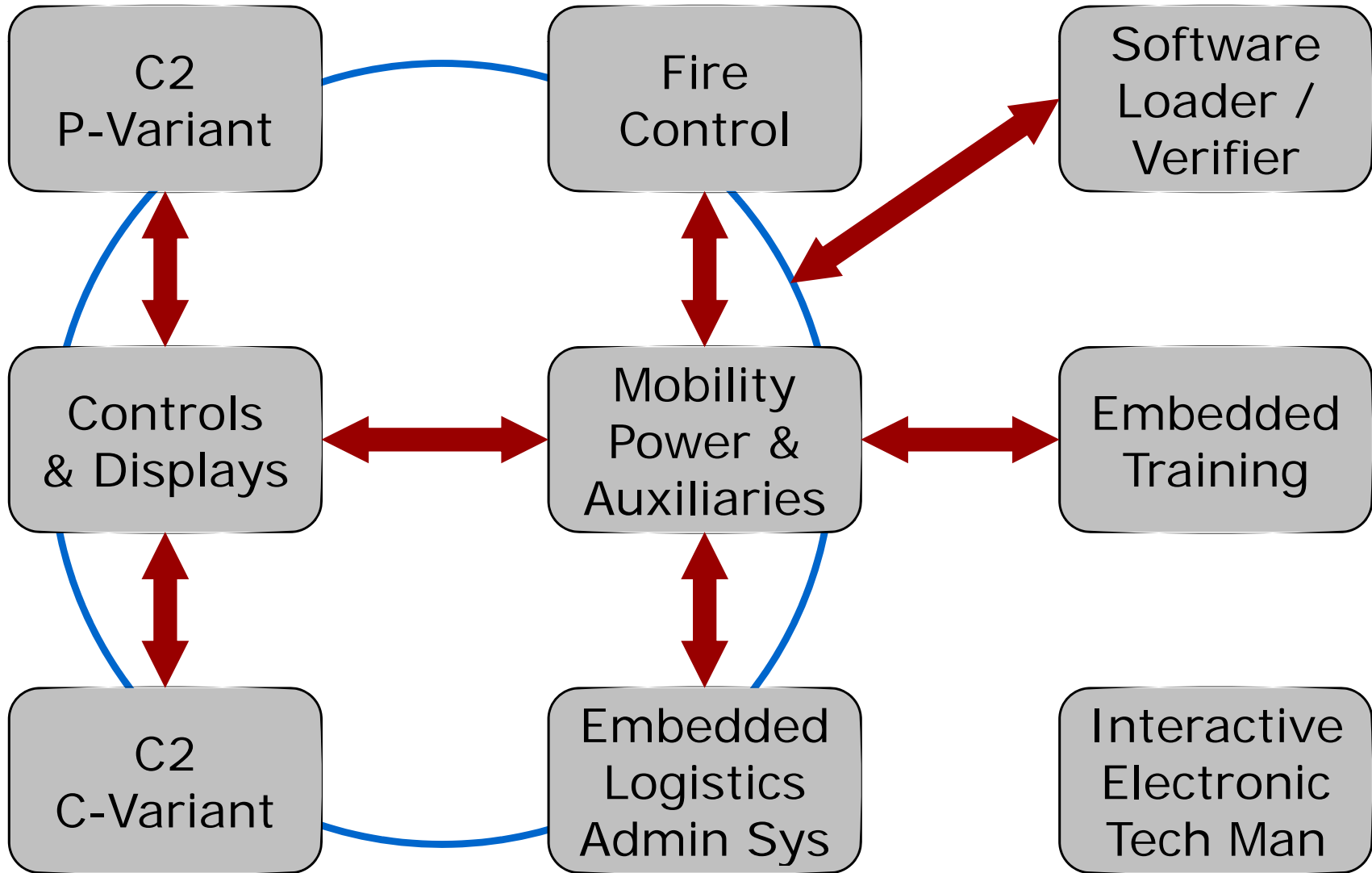


309th SMXG

EFV Software Configured Items



OGDEN AIR LOGISTICS CENTER





309th SMXG

Traditional S/W Quality Measures



OGDEN AIR LOGISTICS CENTER

■ Product

- **Defects Injected** Number of defects introduced within a phase
- **Defects Detected** Number of defects found within a phase
- **Defects Removed** Number of defects removed during a phase

■ Process

- **Defect Injection Rate** Defects injected per hour per phase
 GOAL: **< 0.4 per hour per phase**
 309th Average: **0.03 per 1000 Hours**
- **Defect Detection Ratio** Percent of all defects found internally
 GOAL: **100% at System Test**
 309th Average: **96%**
- **Defect Density** Defects injected per build
 GOAL: **Zero Defects at System Test**
 309th Average: **0.2 Defects per 1000 SLOC**
- **Percent Rework** Percent of total effort required to fix defects
 GOAL: **< 10%**
 309th Average: **2%**



309th SMXG

Tracking Total Defects



OGDEN AIR LOGISTICS CENTER

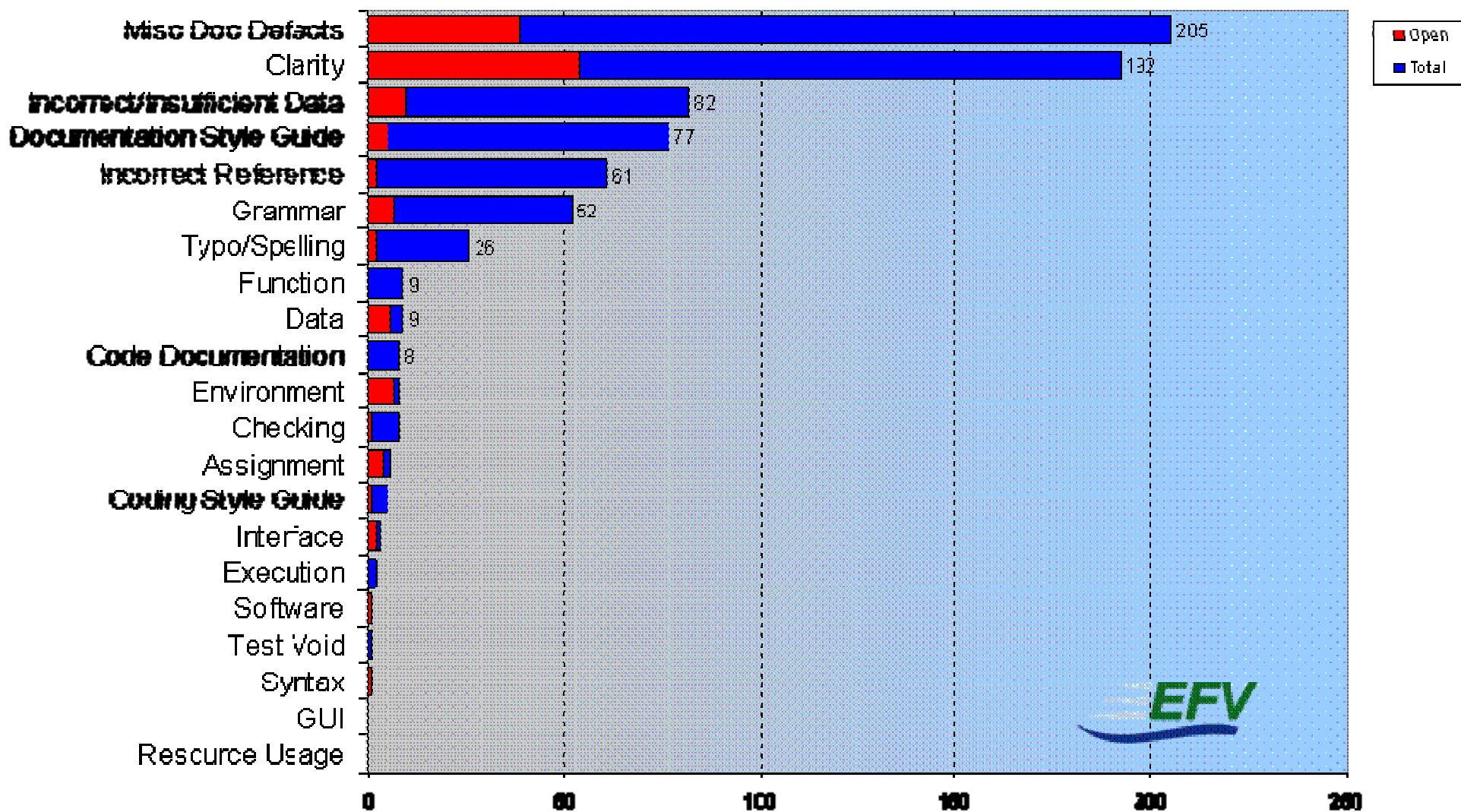




309th SMXG Tracking Defect Types



OGDEN AIR LOGISTICS CENTER

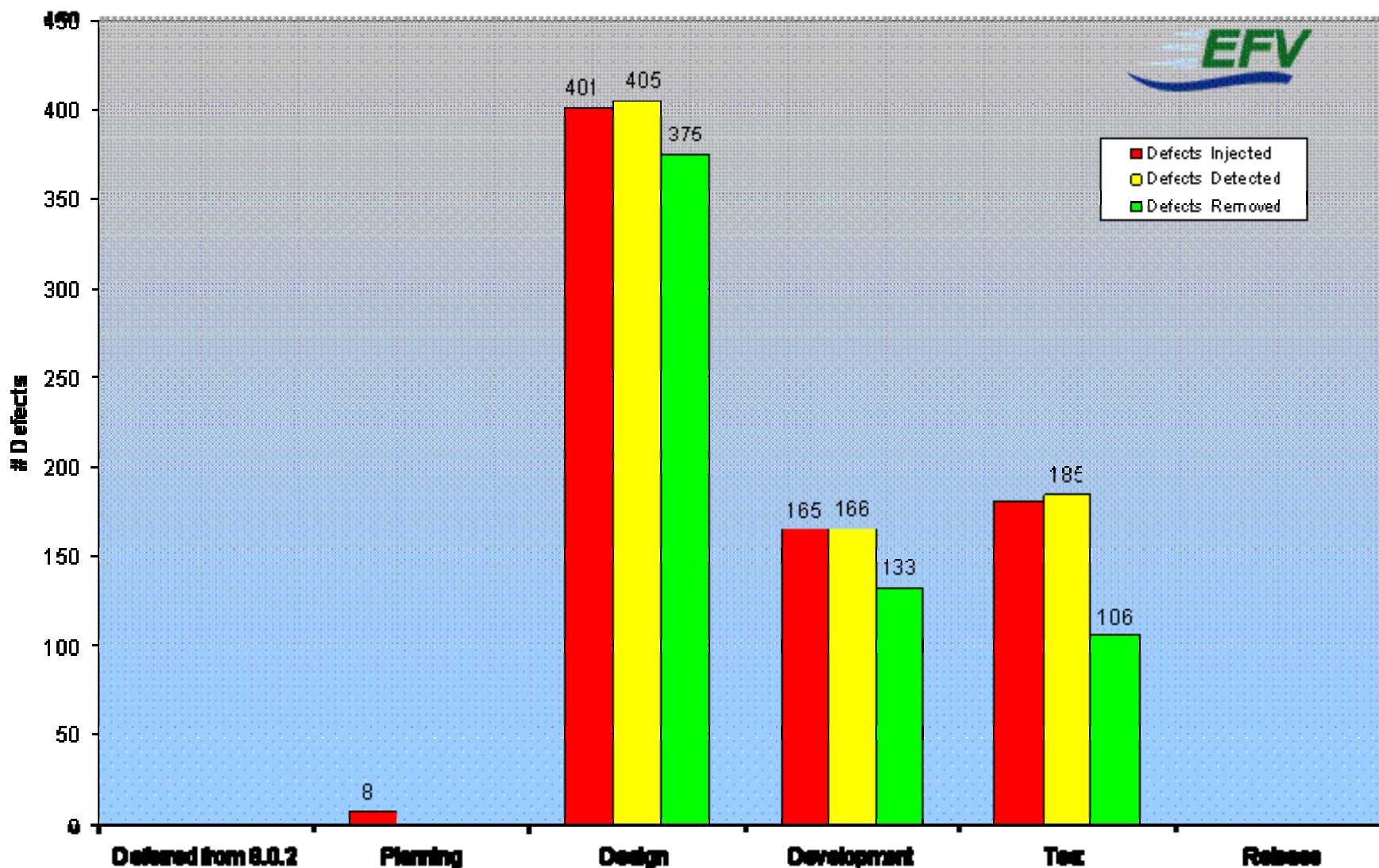




309th SMXG Tracking Product Quality



OGDEN AIR LOGISTICS CENTER





Software Reliability



OGDEN AIR LOGISTICS CENTER

■ Software Reliability Issues

- How do we measure / control the process “up stream?”
- What measures do we take?
 - Process Quality
 - Product Quality
 - The “ilities”
 - Install-ability
 - Usability
 - Flexibility
 - Maintainability
 - Portability
 - Etc.
- While much has been written about this, there is no common way of evaluating software reliability other than tracking defect rates
- It is difficult to track software reliability issues and make mid-course corrections



The TSPSM Process Quality Index – 1



OGDEN AIR LOGISTICS CENTER

- The Software Engineering Institute has developed a tool for use the Team Software ProcessSM teams to measure quality
- Teams measure the quality of the *process* used to produce their software in terms of *measurable goals*
- A high quality *process* typically produces a high quality *product*
- The TSP Process Quality Index (PQI) is a product of five factors:
 - Design Time (Goal: Design Time \geq Code Time)
 - Review Time (Goal: Review Time \geq 50% of Phase Time)
 - Compile Defect Density (Goal: \leq 10 defects/KLOC)
 - Unit Test Defect Density (Goal: \leq 5 defects/KLOC)
- TSP PQI goals are adjusted so that “1” represents meeting the goal

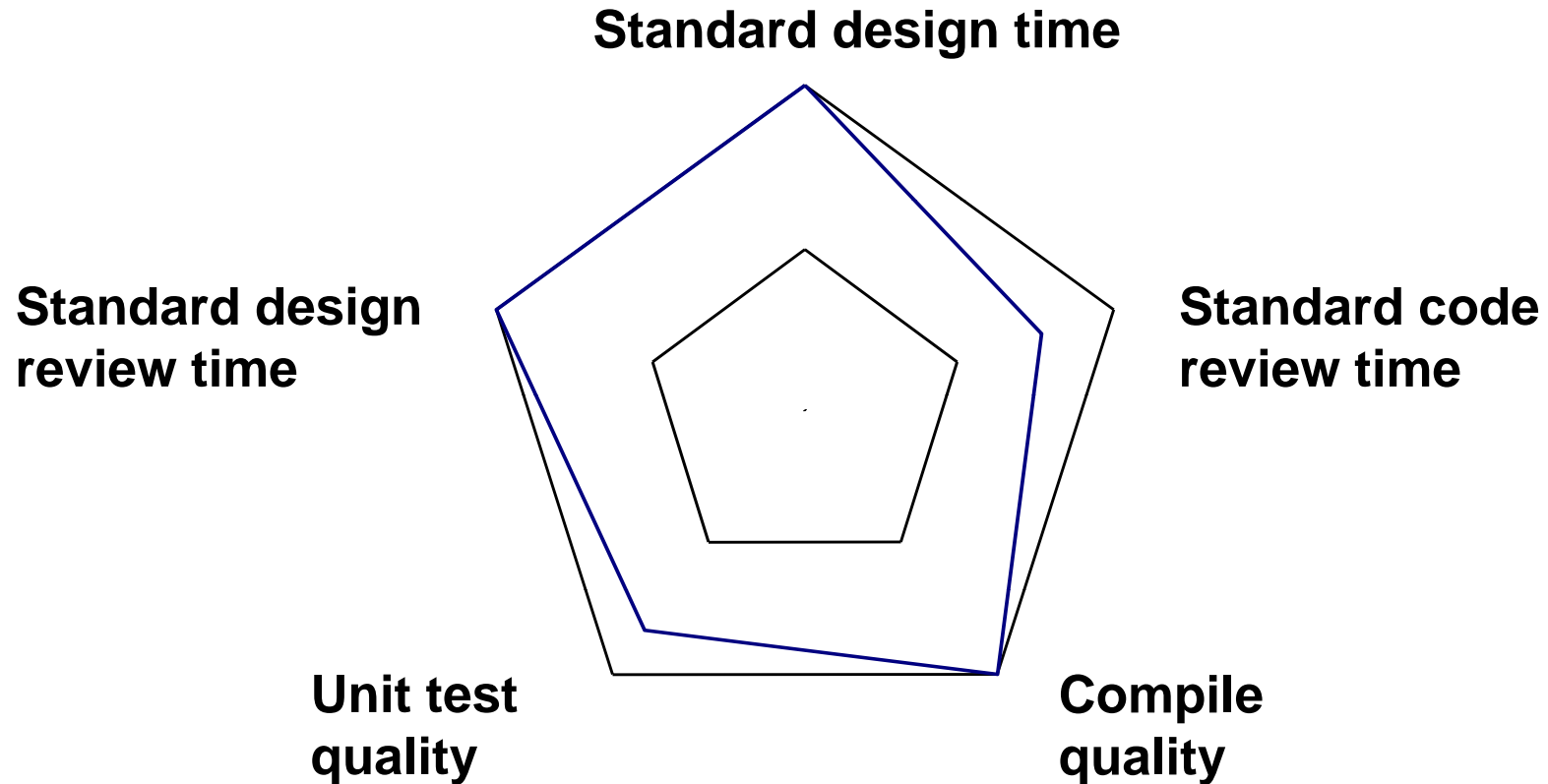
SMTeam Software Process and TSP are Service Marks of Carnegie Mellon University



The TSP PQI – 2



OGDEN AIR LOGISTICS CENTER



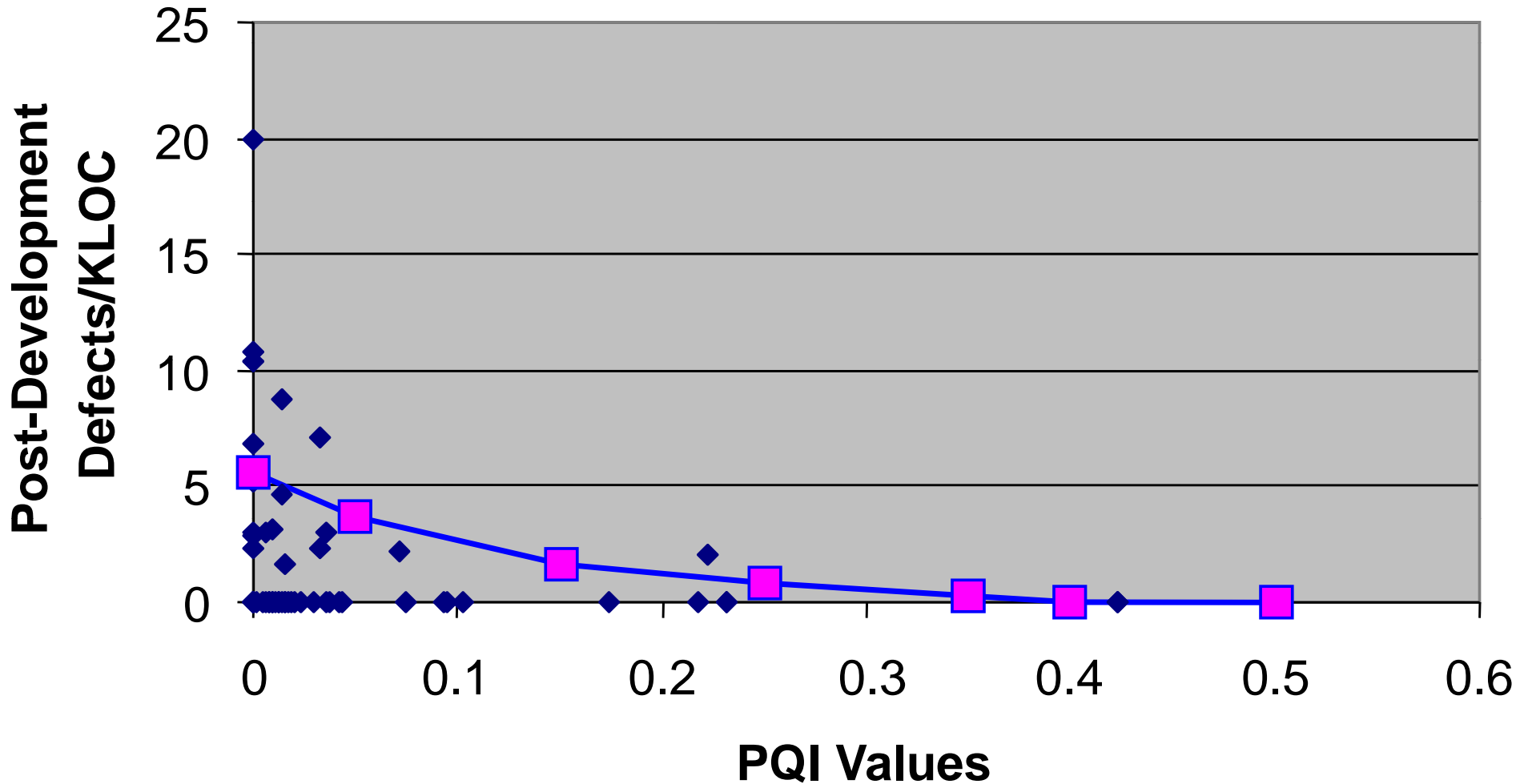
Source: Software Engineering Institute's "Managing TSP Teams" © 2006 by Carnegie Mellon University



PQI vs. Post-development Defects



OGDEN AIR LOGISTICS CENTER



Source: Software Engineering Institute's "Managing TSP Teams" © 2006 by Carnegie Mellon University

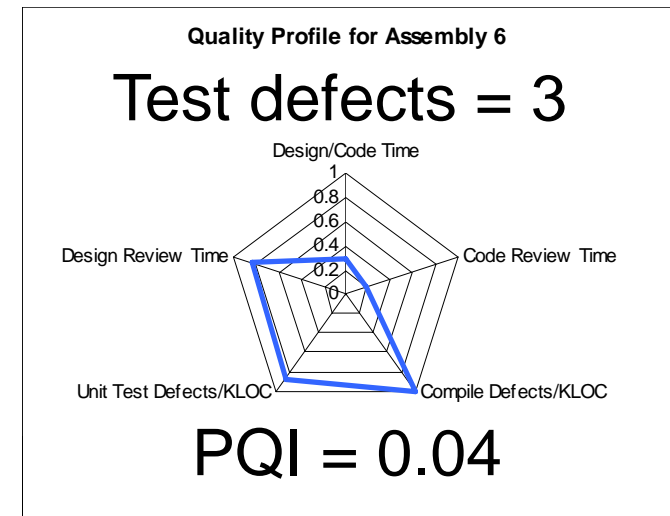
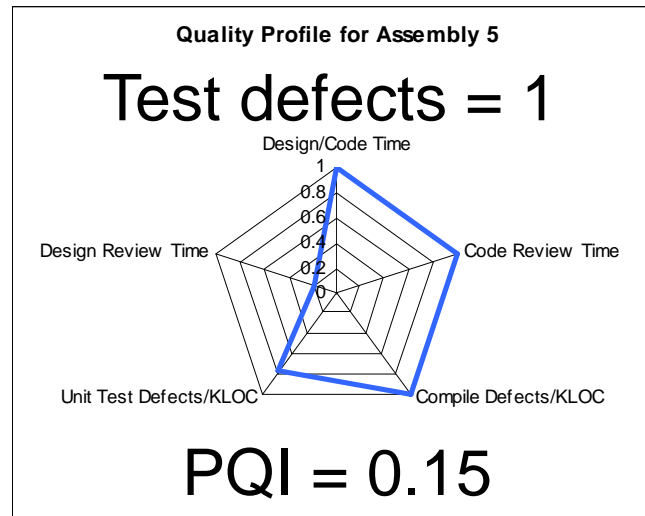
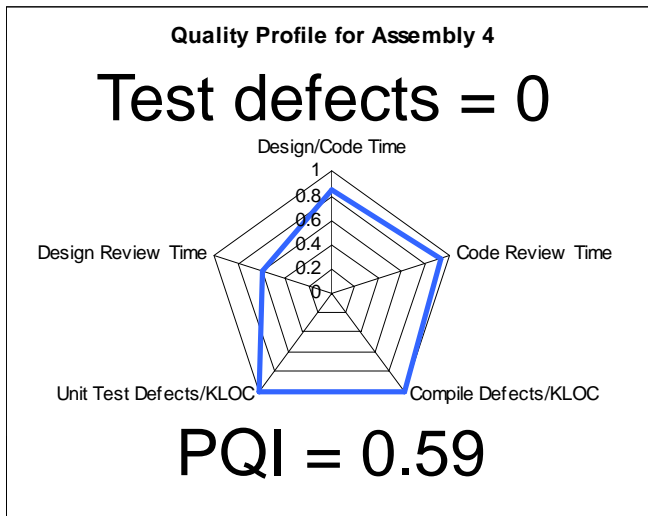
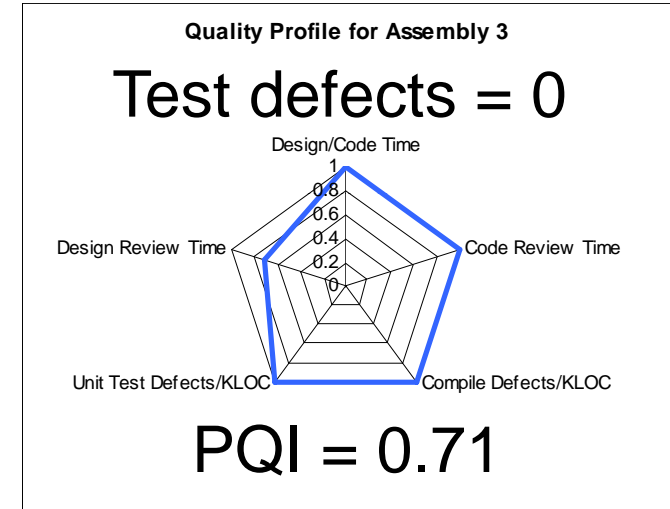
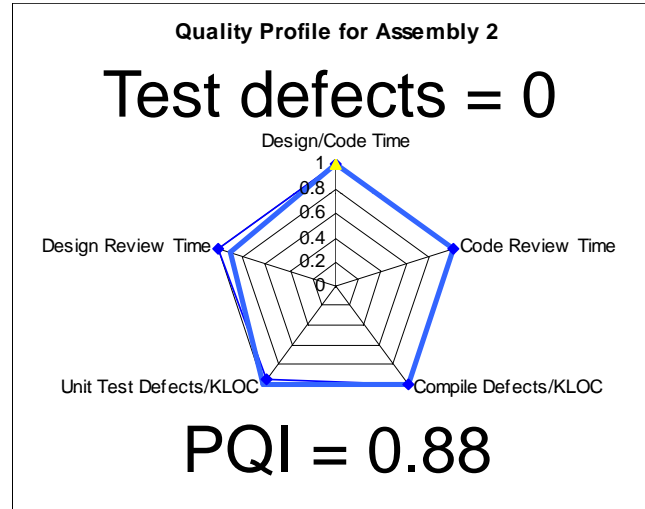
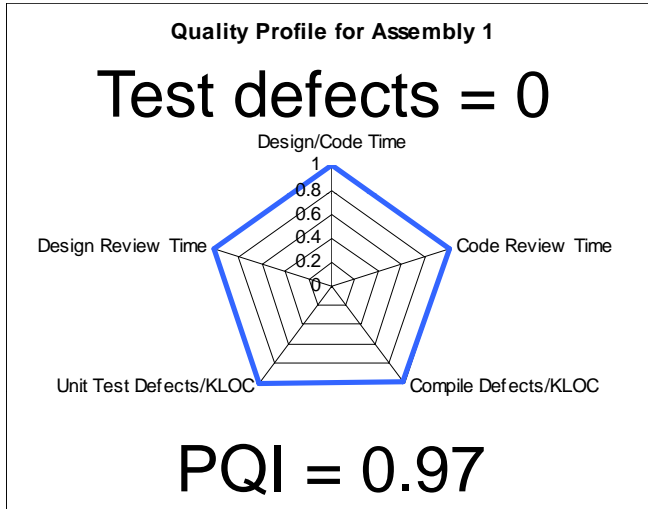


Selected TSP Quality Profiles



OGDEN AIR LOGISTICS CENTER

Source: Software Engineering Institute's "Managing TSP Teams" © 2006 by Carnegie Mellon University





Software Reliability Index (SRI)



OGDEN AIR LOGISTICS CENTER

■ The SRI Must:

- Be measurable throughout the software lifecycle
- Be independent of the software lifecycle selected (waterfall, spiral, iterative, etc.)
- Provide early warning signs of reliability issues
- Provide ability to make effective mid-course corrections

■ SRI Format:

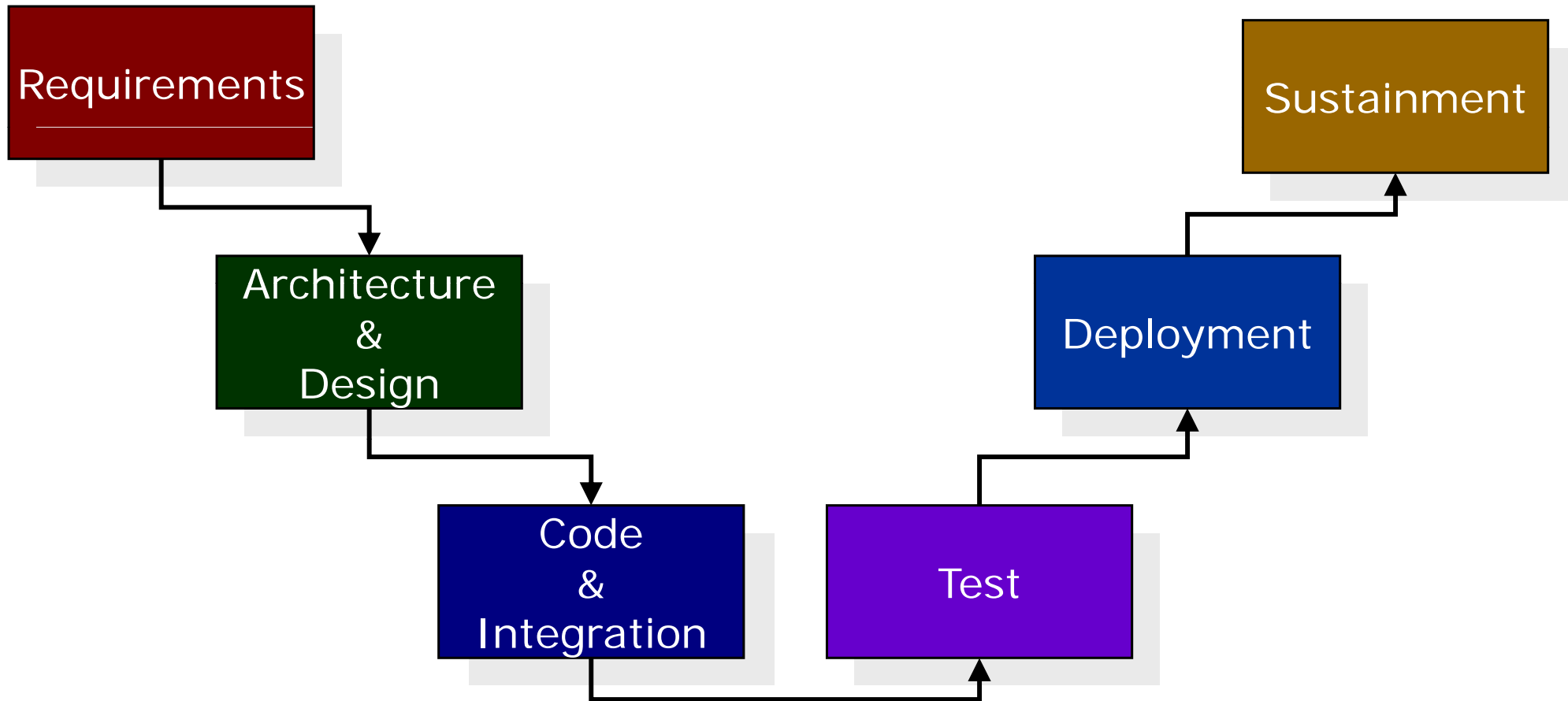
- A format similar to TSP PQI would be helpful
- As in TSP PQI, a set of measurable objectives that promote high reliability would be required
- Measures must be adjusted to a number between 0 (unreliable) and 1 (highly reliable)
- Measures must directly point to possible reliability issues
- One approach is to use measurements from each software lifecycle phase



Software Lifecycle Typical Phases



OGDEN AIR LOGISTICS CENTER





Software Lifecycle Using Phases



OGDEN AIR LOGISTICS CENTER

■ Advantages

- While some has been developed for Software Reliability, much has been developed for each lifecycle phase
- It is fairly easy to identify a few key reliability factors in each lifecycle phase
- Each lifecycle phase could, in fact, have its own reliability index which would then feed into the overall index

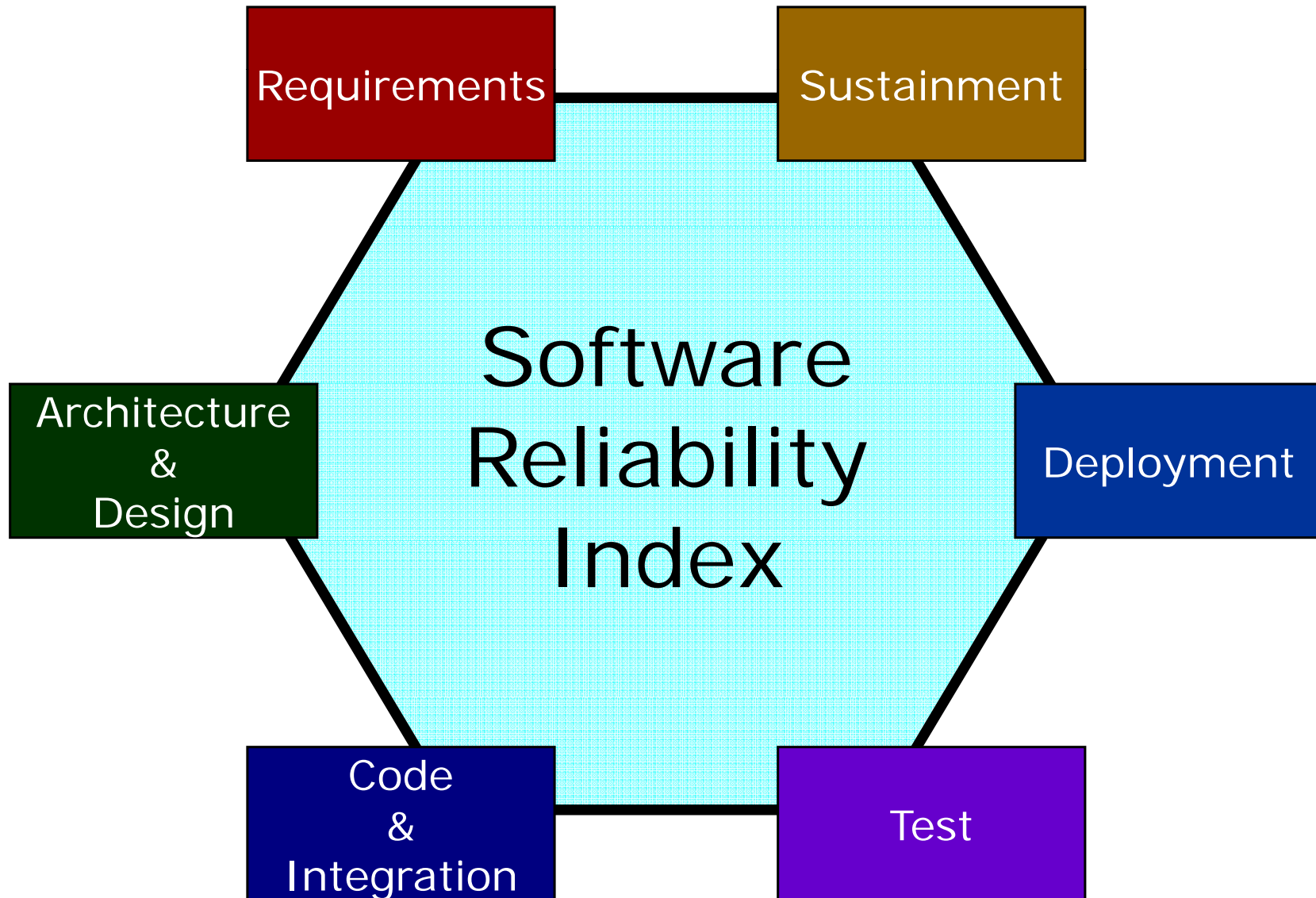
■ Disadvantages

- While there is a lot of data for each lifecycle phase, the data have never been correlated to true reliability
- Since there is little data on what constitutes reliability, it makes validating any reliability model difficult



SRI Parameters

OGDEN AIR LOGISTICS CENTER

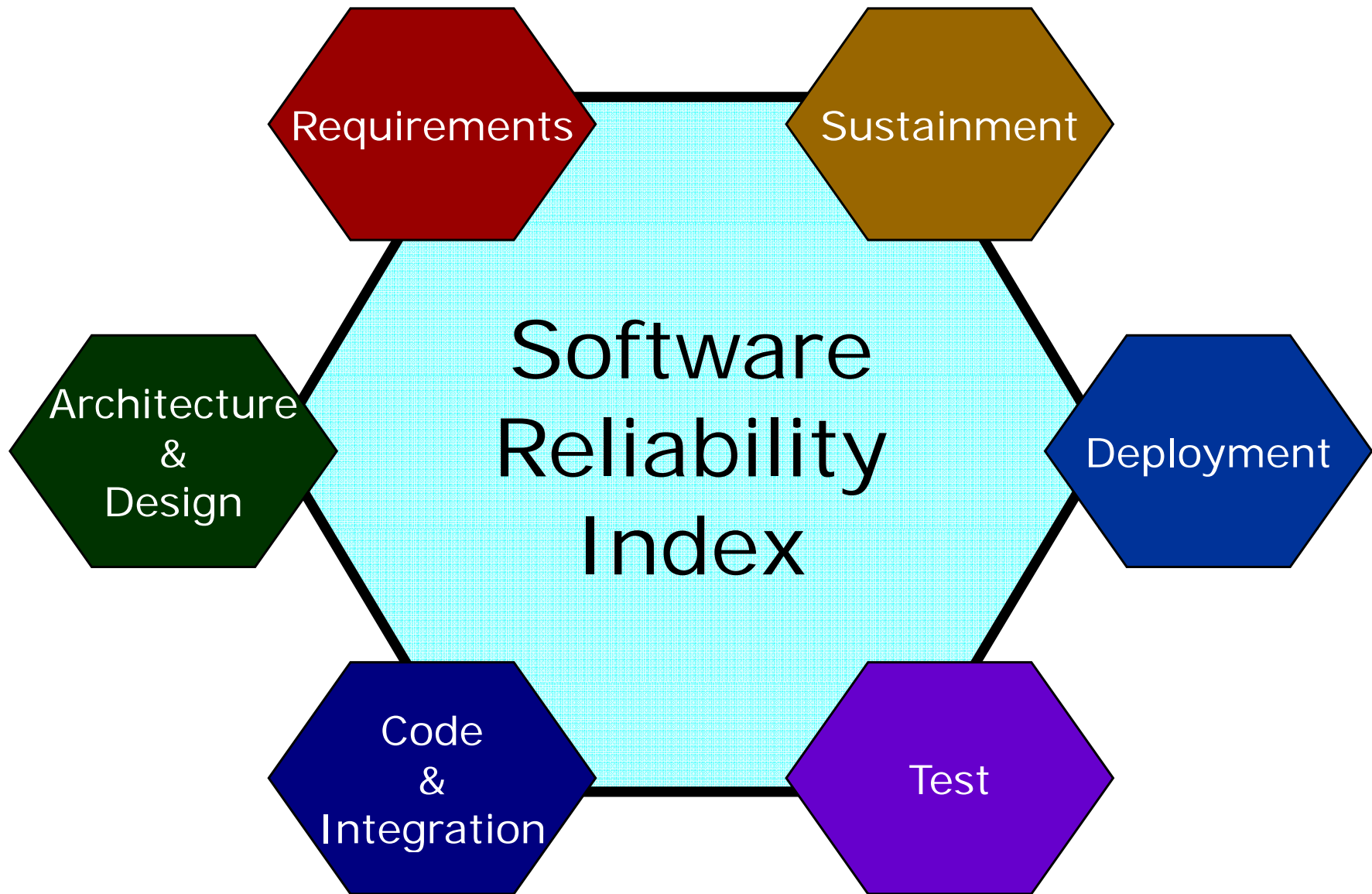




SRI Parameters



OGDEN AIR LOGISTICS CENTER



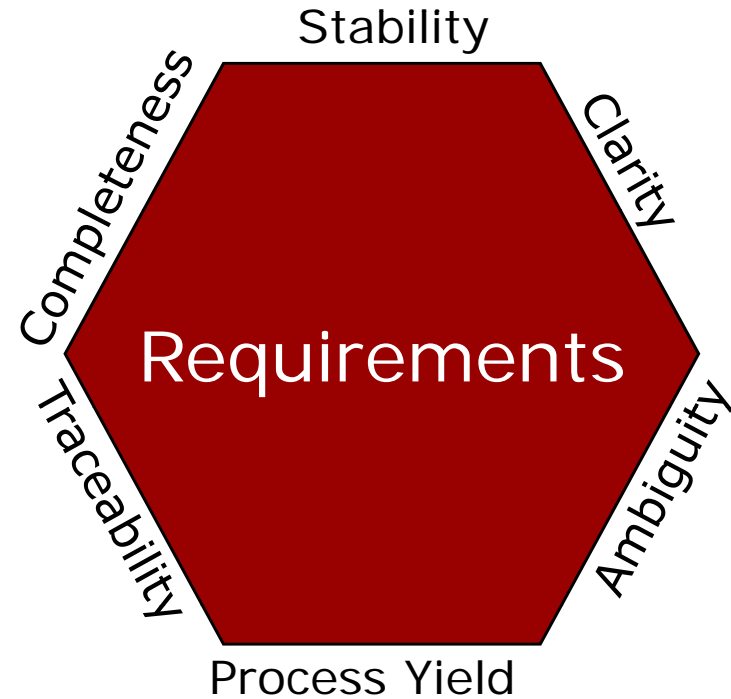


Software Reliability Index Requirements



OGDEN AIR LOGISTICS CENTER

- **Stability**
 - The percent of unchanged requirements per release
 - A new or deleted requirement is a changed requirement
- **Clarity**
 - The percent of requirements that are clear and understandable
- **Completeness**
 - The percent of requirements without TBDs, TBRs, TBAs, etc.
- **Ambiguity**
 - The percent of requirements with potential multiple meanings
- **Traceability**
 - The percent of requirements traced upward to a higher level document and traced to a lower level design component
- **Process Yield**
 - The percent of defects removed



SRI_R

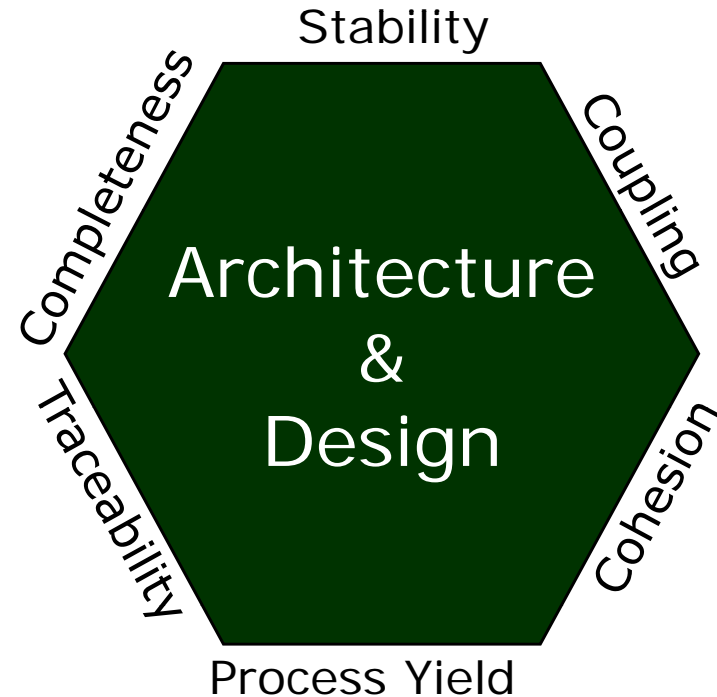


Software Reliability Index Architecture & Design



OGDEN AIR LOGISTICS CENTER

- **Stability**
 - The percent of unchanged platform components
 - A new or deleted component is a changed component
- **Interface Definition Completeness**
 - The percent of completeness of Interface Control Documents
- **Design Coupling**
 - The percent of modules that exhibit low coupling
- **Design Cohesion**
 - The percent of modules that exhibit high cohesion
- **Traceability**
 - The percent of requirements traced upward to a higher level document and traced to a lower level design component
- **Process Yield**
 - The percent of defects removed



SRI_A



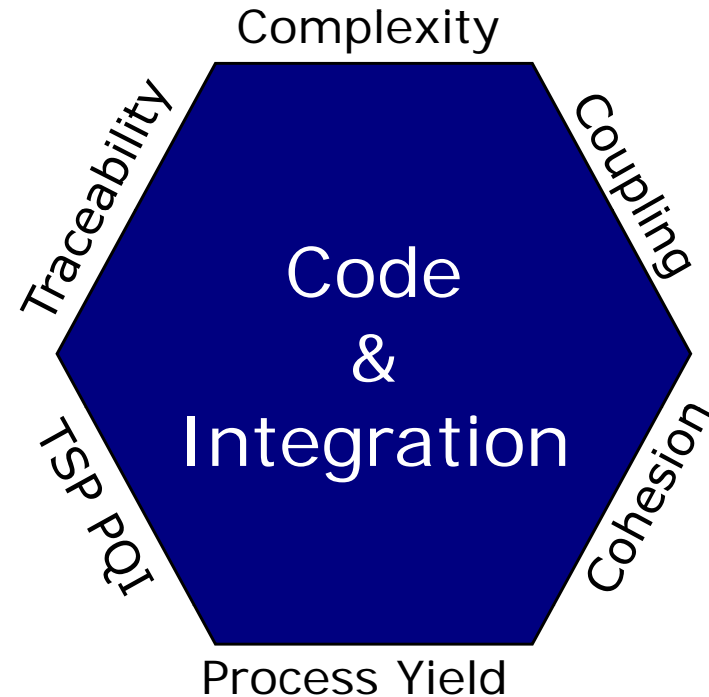
Software Reliability Index

Code & Integration



OGDEN AIR LOGISTICS CENTER

- **Cyclomatic Complexity**
 - McCabe Cyclomatic Complexity
- **Code Coupling**
 - The percent of modules that exhibit low coupling
- **Code Cohesion**
 - The percent of modules that exhibit high cohesion
- **Traceability**
 - The percent of requirements traced upward to a higher level document and traced to a lower level design component
- **Process Quality Index (PQI)**
 - The combined TSP PQI measure for all modules
- **Process Yield**
 - The percent of defects removed



SRI_C

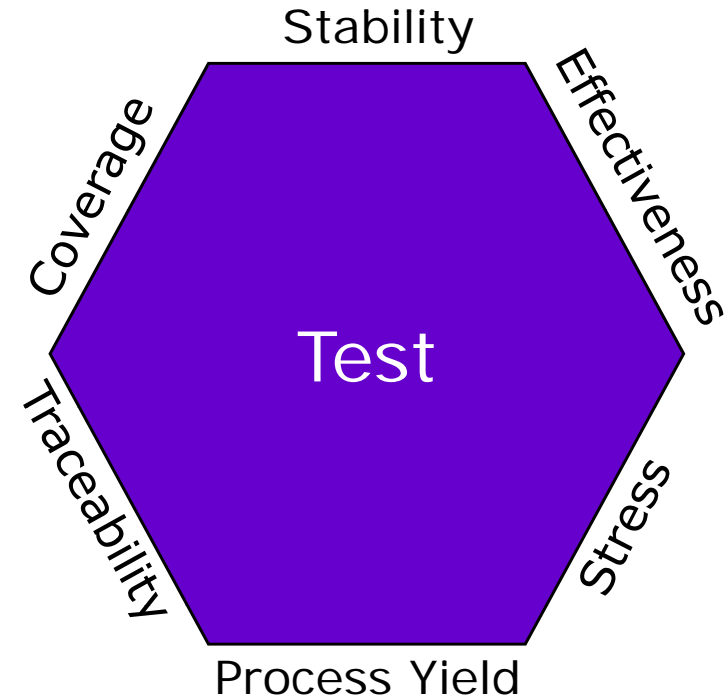


Software Reliability Index Test



OGDEN AIR LOGISTICS CENTER

- **Coverage**
 - The percent of requirements covered through testing
- **Effectiveness**
 - The level of confidence that existing defects are being found through testing
- **Stress**
 - The percentage of system components tested outside the expected limits
- **Stability**
 - The percent of requirements tested relative to the requirements implemented
- **Traceability**
 - The percent of requirements traced upward to a higher level document
- **Process Yield**
 - The percent of defects removed



SRI_T

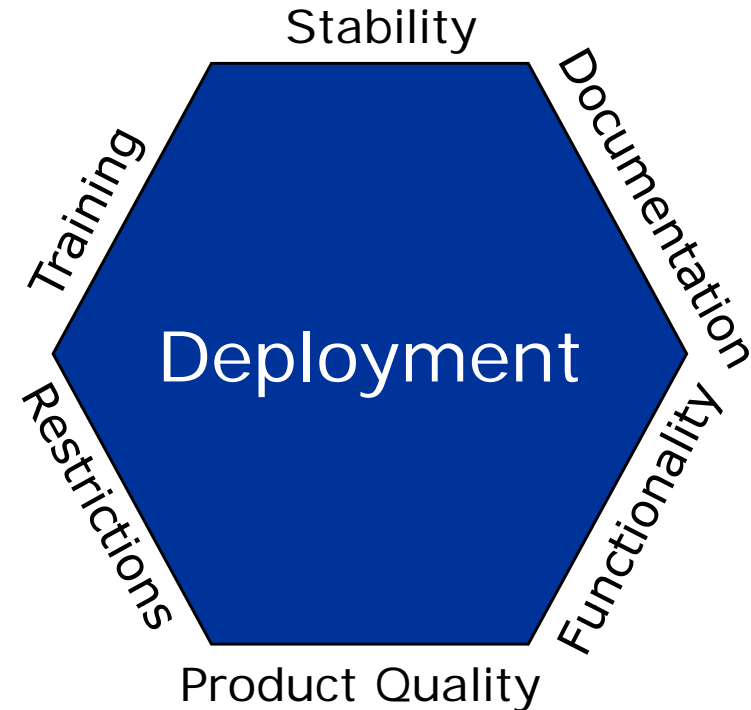


Software Reliability Index Deployment



OGDEN AIR LOGISTICS CENTER

- **Training**
 - The percentage of system features covered by training prior to deployment
- **Documentation**
 - The percentage of required documentation completed at time of deployment
- **Stability**
 - The percentage of the implemented system that is fully configured and supported at deployment
- **Functionality**
 - The percent of the total system requirements implemented at time of deployment
- **Restrictions**
 - The percent of implemented system requirements that are fully functional
- **Product Quality**
 - The percent of total defects found prior to deployment



SRI_D

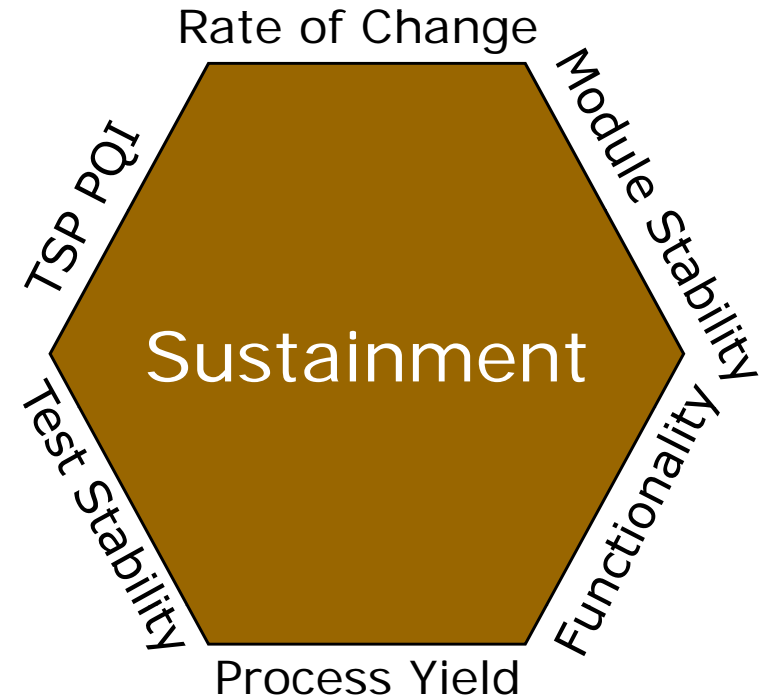


Software Reliability Index Sustainment



OGDEN AIR LOGISTICS CENTER

- **Rate of Change**
 - Percent of requirements unchanged per month
- **Module Stability**
 - Percent of total software modules unchanged
- **TSP Process Quality Index**
 - The combined TSP PQI measure for all updated modules
- **Test Stability**
 - The percent of requirements tested relative to the requirements implemented
- **Functionality**
 - The percent of functional improvement over the original release
- **Process Yield**
 - The percent of defects removed

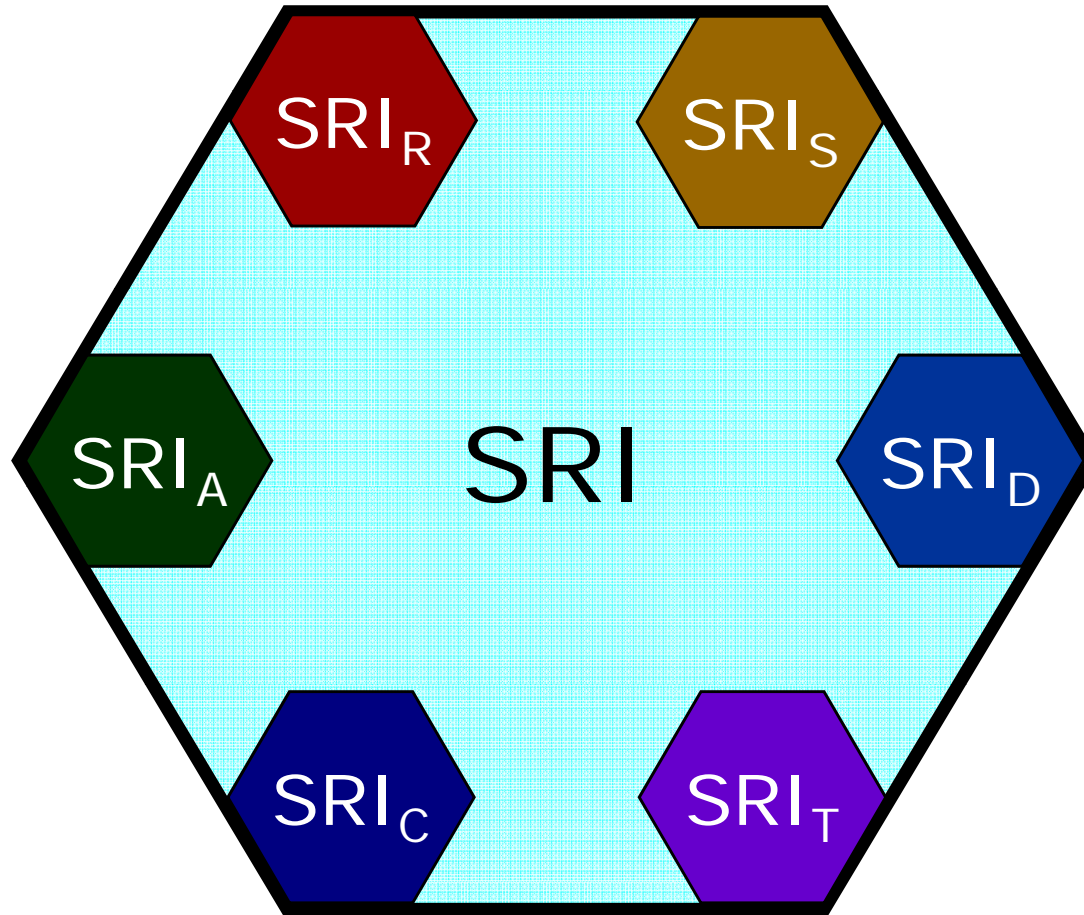


SRI_s



Software Reliability Index

OGDEN AIR LOGISTICS CENTER



$$SRI = SRI_R * SRI_A * SRI_C * SRI_T * SRI_D * SRI_S$$



Pros and Cons



OGDEN AIR LOGISTICS CENTER

■ Pros

- Each lifecycle phase can be measured independently or in concert with the others
- Data on each lifecycle phase are derived from data which are typically collected in these phases
- Collection and examination of these data encourages a high maturity approach to the software development life cycle, which has been proven to produce reliable software

■ Cons

- 36 is a large number of factors, many of which may not be controllable
- Statistical analysis of these factors has not been conducted to determine the relevance of each to SRI
- The index may be unstable, since the SRI is a product of products and a major variation of any one factor or minor variations of several factors can have a major influence on the outcome



Conclusions



OGDEN AIR LOGISTICS CENTER

- **Software does not wear out like Hardware, but its Reliability is an important contributor to overall System Reliability**
- **Most measures for Software Reliability concentrate on the Development or Testing phases**
- **Full-lifecycle (i.e. Requirements phase through to Sustainment phase) reliability measures potentially provide a more comprehensive assessment**
- **An overall Software Reliability Index (SRI) can be computed as a product of Reliability Indices from each lifecycle phase**
- **The SRI can be used to track reliability over time, used as a predictor to compare with actual reliability, or to identify areas of improvement that will increase reliability**
- **The SRI model presented here is just now being put into practice for EFV software and evidence of its efficacy will be published at a later date**



OGDEN AIR LOGISTICS CENTER

Questions???



Contact Information



OGDEN AIR LOGISTICS CENTER

- **The MITRE Corporation / PM AAA, USMC**

Robert J. Knapper

(703) 496-9237

rknapper@mitre.org

knapperrj.ctr@efv.usmc.mil

- **309th Software Maintenance Group/
520th Software Sustainment Squadron**

David R. Webb

(801) 586-9330

david.webb@hill.af.mil

David L. Jolley

(801) 777-3823

david.jolley@hill.af.mil