NAVSEA WARFARE CENTERS NEWPORT

Sensors & SONAR Systems DEPARTMENT

Two-Step Methodology to Reduce Software System Requirement Defects

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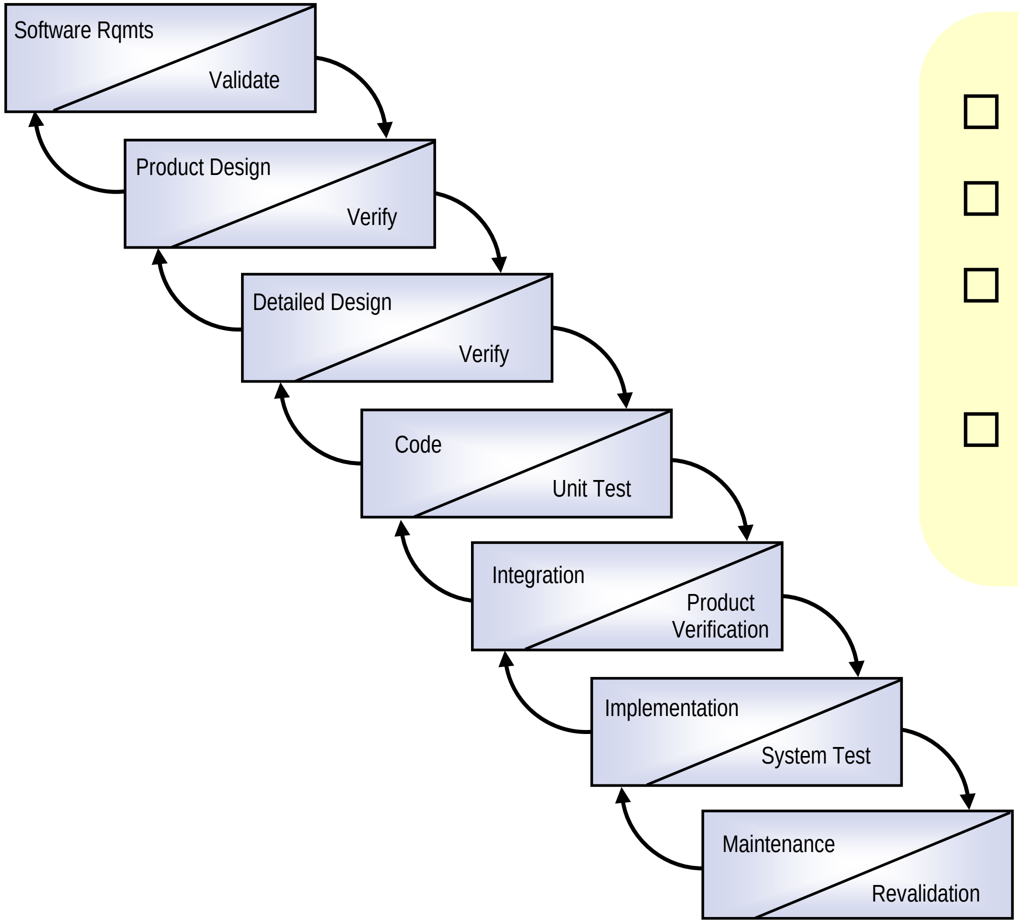
Software System Development

“Typical”
Software System Development



- □ **Waterfall / Incremental model**
- □ **Spiral model similar for a spiral**
- □ **Implies a sequential process to resolve problems (defects)**
- □ **Does not provide an adequate illustration of defect impacts**

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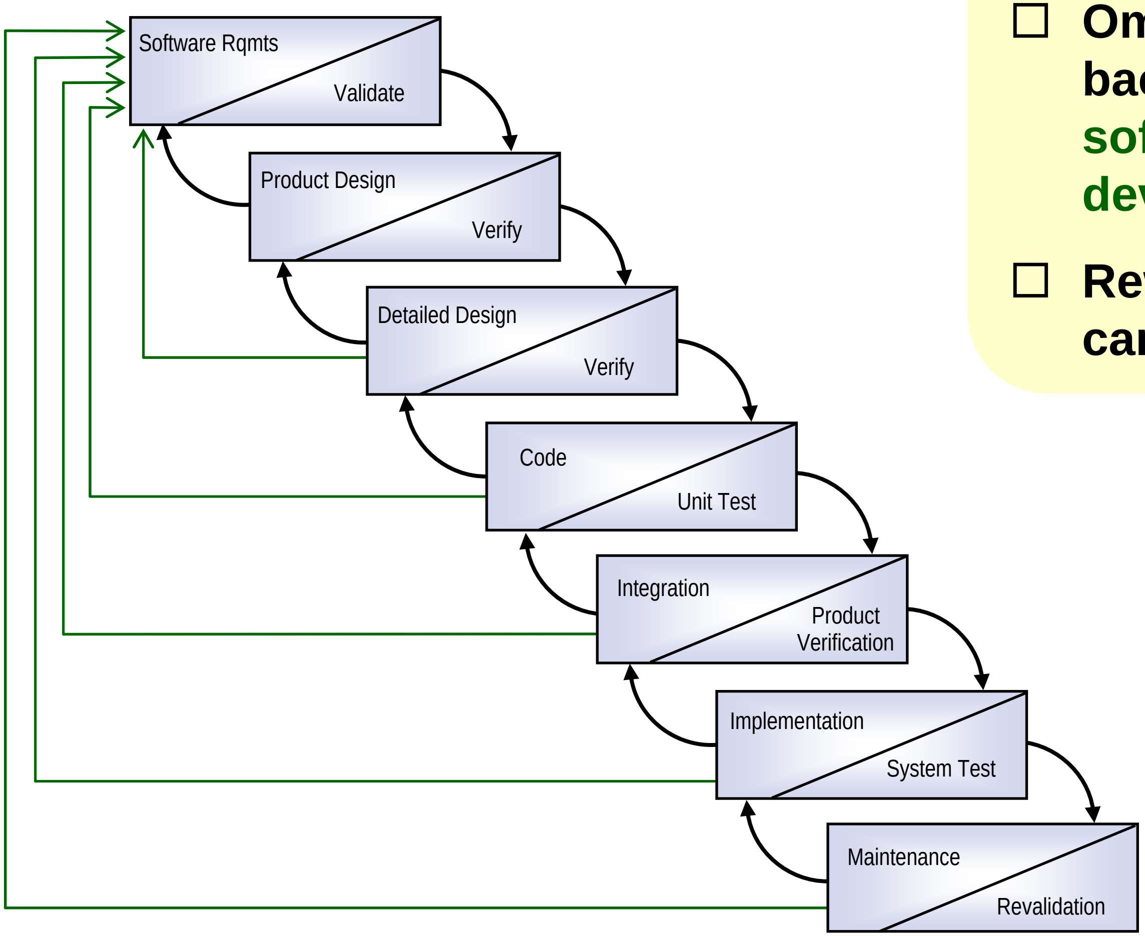
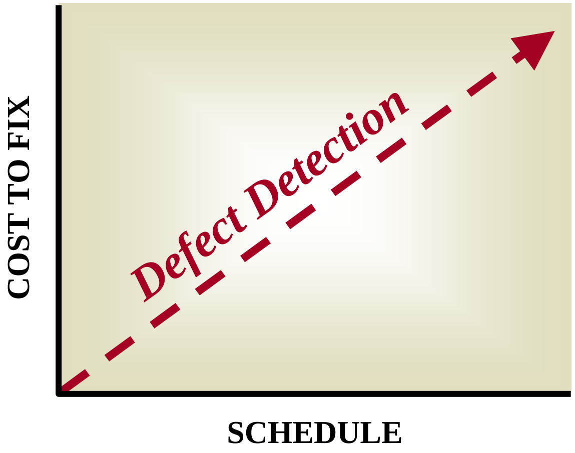
Software System Development

“Realistic”
Software System Development



- □ **Added links backwards to reflect origin of defects**
- □ **Omitted links other than those back to the first phase – software system requirements development**
- □ **Rework caused by defects can impact cost and schedule**



Software System Development

DEFECTS AND REWORK

$ Rework caused by defects can impact cost and schedule

$ The later a defect is found, the greater the cost to correct

$ Defects found and fixed in later phases of development can cost up to 100x the cost to correct if detected in early phases

- Software Specifications
- S/W designs, code, test, documentation
- Integration, T&E plans and procedures
- Integrated Logistics Support (ILS) products (Operator / User manuals, Training materials, etc)
- Distribution costs
- Change documentation

REQUIREMENT DEFECTS

- *Impacts all phases and products (“Negative Ripple Effect”)*
- *Most costly to correct*
- *Cause delays in schedule and product delivery*
- *Initial system may have reduced capability and functionality, and most likely operational limitations*
- *Usually require formal documentation to correct, e.g., Engineering Change Proposal (ECP)*

DEFECT CORRECTION EXPENDS RESOURCES AND FUNDS REQUIRED FOR PLANNED SYSTEM CAPABILITIES

S/W System Requirement Defects

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

- □ **When:**
  - ● Focus on software development phase of acquisition; initial development or maintenance phase
  - ● Prior to Software Specification Review (SRR) and Preliminary Design Review (PDR)
    - » Low-level, defect detection process prior to high-level, program milestone review
    - » Process generates better products input to SRR and PDR, or an Engineering Change Proposal (ECP) during life-cycle maintenance phase
  - ● Used during system software specification generation, i.e., during translation of high level Performance Specification and user requirements (CONOPS) or User Requirements Document into low-level Software Requirement Specifications (SRSs)
  - ● Systems Engineering (SE) organizes and runs the **defect detection process**
    - » SE oversees technical aspects of the entire system acquisition, including processes to find defects in **ALL** products

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S/W System Requirement DefectS

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

□ **How:**

- Analysis on past defects identifies two basic types of s/w system requirement defects
- The defect that is unintentionally introduced into the s/w system requirement specifications during specification generation
  - » Ambiguous text
  - » Equation errors (algorithms)
  - » Figure errors (functional and processing flows)
  - » Table errors (wrong units, input ranges, etc.)
  - » Connectivity and inconsistency issues
  - » Missing or incomplete requirements

CAUTION

S/W engineers will fill in the 'holes' and 'gaps'

- The defect that causes effort to be expended producing unnecessary, incorrect or unwanted functionality
  - » "Bells and whistles"
  - » Inadequate graphical user interface (GUI)
    - – Systems are becoming more user interface driven (COTS) so the proposed GUI should be included in the s/w specification

Need to eliminate user comments like, "system should work this way"

S/W System Requirement Defects

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

□ **How:**

- Develop methodology/process to address both types of s/w system requirement defects
- First, tackle the mistakes made translating P-Spec and User specifications/CONOPS into functional flows and the GUI
  - » "Bells and whistles"
  - » Unnecessary, incorrect or unwanted functionality
- Second, tackle the mistakes made generating the s/w system requirements specifications
  - » Usual mistakes made producing specifications, e.g., ambiguous text, etc.

S/W System Requirement Defects

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

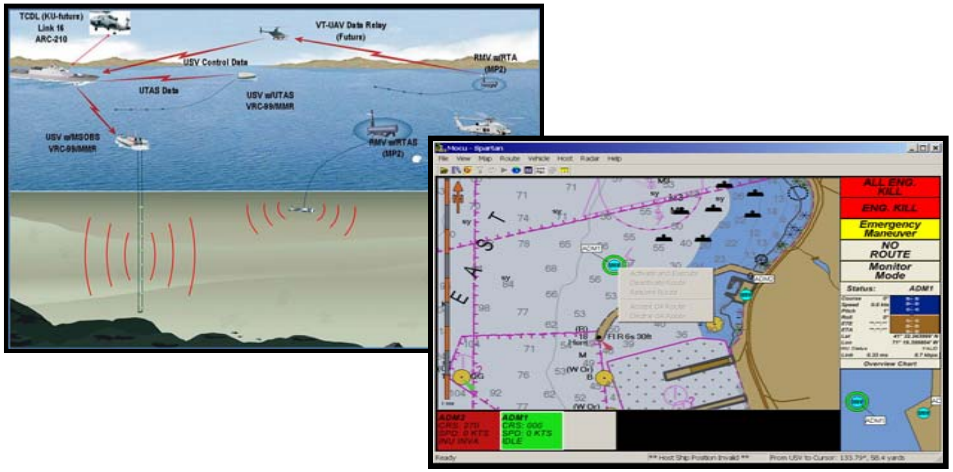
- □ **Introduce a two-step methodology for s/w system requirements clean-up**

  1: Operational Demonstration (OP-DEMO) of the User Requirements

  - » Visual demonstration of proposed GUI and functional flows
  - » Allows evaluation of system functionality prior to development

  2: S/W Inspection conducted on software requirement specifications

  - » Rigorous review originally developed for s/w but can be applied to any “readable” products



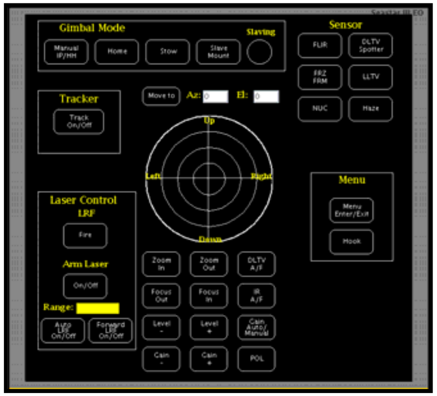
Step 1: OP-DEMO

□ Visualization of the User Requirements

- Operability and functional flow
- Graphical User Interface (GUI)
- Target Machine or other

□ Different levels of OP-DEMO

- Operability features and functional flow
- Operability features and functional flow with limited processing (e.g., algorithms)



□ Form of Software Rapid Prototyping

- Disposable code
- Developed FAST using appropriate tools
- User involvement early – during s/w requirements phase

Step 1: OP-DEMO

□ **Wrong Concept of OP-DEMO (prototyping)**

- Target machine is always utilized
- Deliverable code
- Considered ‘full’ system operability
- User involvement in later phases
- Fix problems in maintenance phase

CAUTION

OP-DEMO is Similar to Prototyping and Prototyping Means Different Things to Different People

OP-DEMO Benefits

- □ Involves the User during the early phases, as opposed to the later phases or after system delivery
- □ Eliminates unnecessary and incorrect functionality and helps prioritize remaining functionality
- □ Provides a working model of intended operation for reference, as well as tool to allow parallel development of operator/training materials
- □ Identifies areas of uncertainty for risk management
- □ Promotes faster and more accurate s/w system specification writing

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Step 2: Requirement Inspection (RI)

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

□ **“Software Inspection” applied to the Software System Specifications**

□ **Not like an informal ‘Code Walkthrough’**

□ **Formal, intensive review process designed to detect errors**

- Ambiguous text
- Equation errors (algorithms)
- Figure errors (functional and processing flows)
- Table errors (wrong units, input ranges, etc.)
- Connectivity and inconsistency issues
- Missing or incomplete requirements

□ **Basic characteristics**

- Team approach, with assigned roles (reader, moderator, author)
- Standards of conduct
- Collect metric data
- Criteria for Quality

Documented results indicate up to 85% of design and code errors can be detected by “Software Inspections”

Step 2: Requirement Inspection (RI)

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

- **Team Members**
  - Software Engineer (Lead)
  - System Engineer
  - User (or ILS person)
  - Test Engineer
- **Multiple teams (2 or 3) detect more defects (N-Fold Inspection)**
  - Small % of duplicate defects found between multiple teams

Multiple discipline involvement ensures consistent interpretation of software system requirements across phases

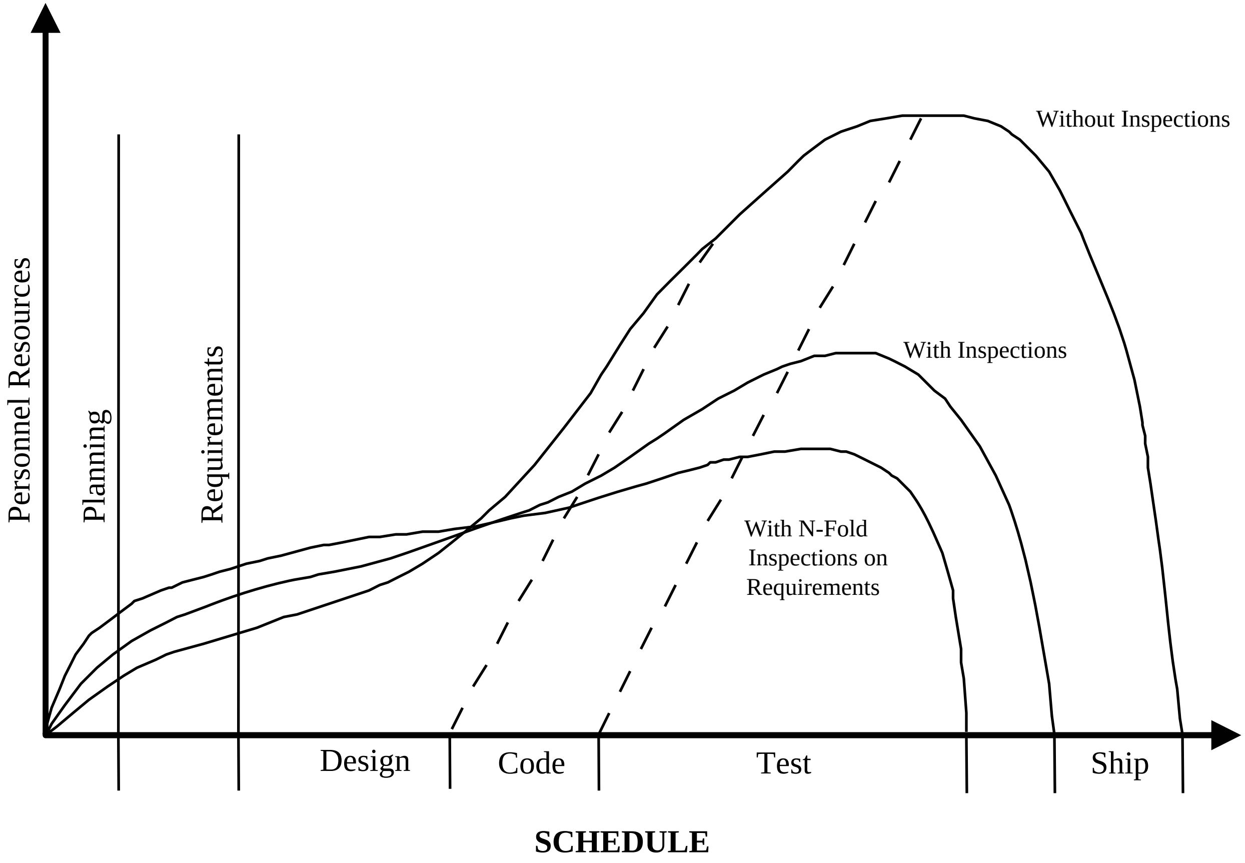
Requirement Inspection Benefits

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

- □ **Ensures User requirements are accurately specified**
- □ **Ensures developer requirements are accurately specified**
- □ **Real-time metric data collection identifies areas of improvement w/ specification generation**
- □ **Errors corrected in single pass versus iterative correction process**
- □ **Detects errors associated with all phases of the Development**
- □ **Low cost / defect ratio**
- □ **Reduces software development costs by detecting errors early, avoids REWORK**

Requirement Inspection Benefits

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS



Impact of RI on Development (modified from [1])

[1] Fagan, M.E., “Advances in Software Inspections,” *IEEE Transactions on Software Engineering,* Vol SE-12, No. 7, July 1986

Case Study

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

□ **Two extensive upgrades to an existing system – approx 100 KSLOC each**

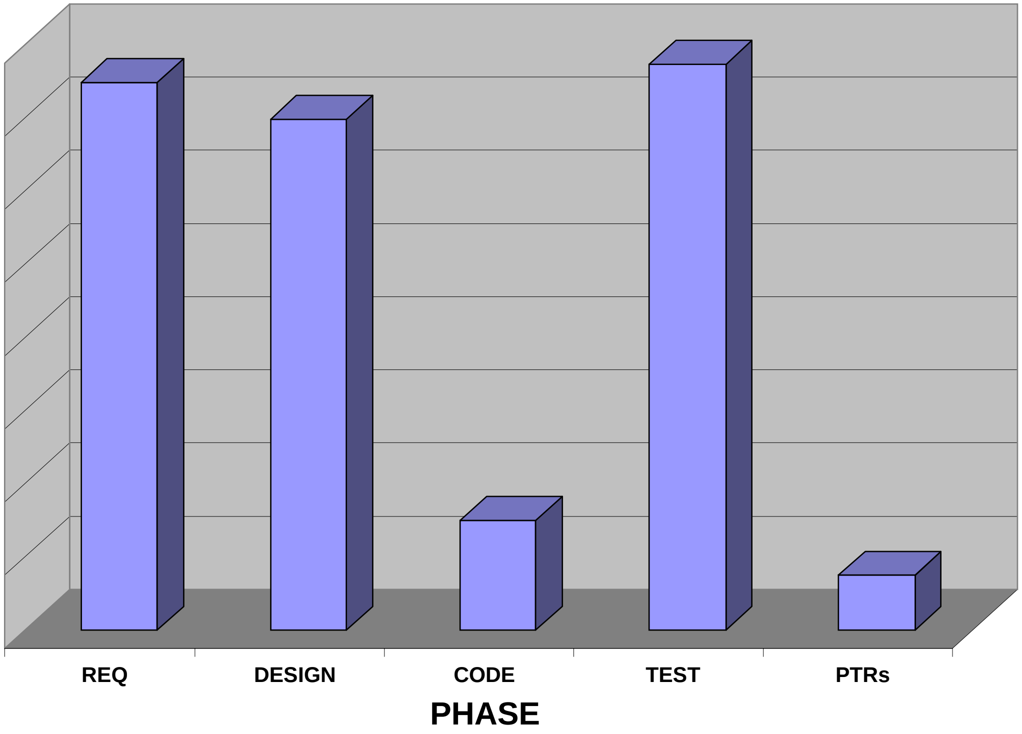
- Existing system was really a “prototype/experimental” system delivered as a production system; so had to fix in Maintenance phase via ECPs
- First upgrade did not use 2-Step Methodology to reduce Software System Requirement Defects; second upgrade did
- Software System Specifications for first upgrade were developed by SE with only informal reviews, and significant portion of user interface was “TBD/TBS”
- Software development team was already using Software Inspection during development so extensive defect metric data was collected during both upgrades
- Causal analysis was conducted on all defects found to determine origin of defect
- Both types of OP-DEMO were utilized on second upgrade (algorithms); 2-Fold RI also used on second upgrade

Case Study

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

Upgrade 1 Observations

Requirement Defects By Phase - UPGRADE 1



$ Informal reviews found some defects but not enough

$ Defects found during Design and Code could have been found by RI

$ Defects found during computer-based Test and Post-delivery could have been found by OP-DEMO

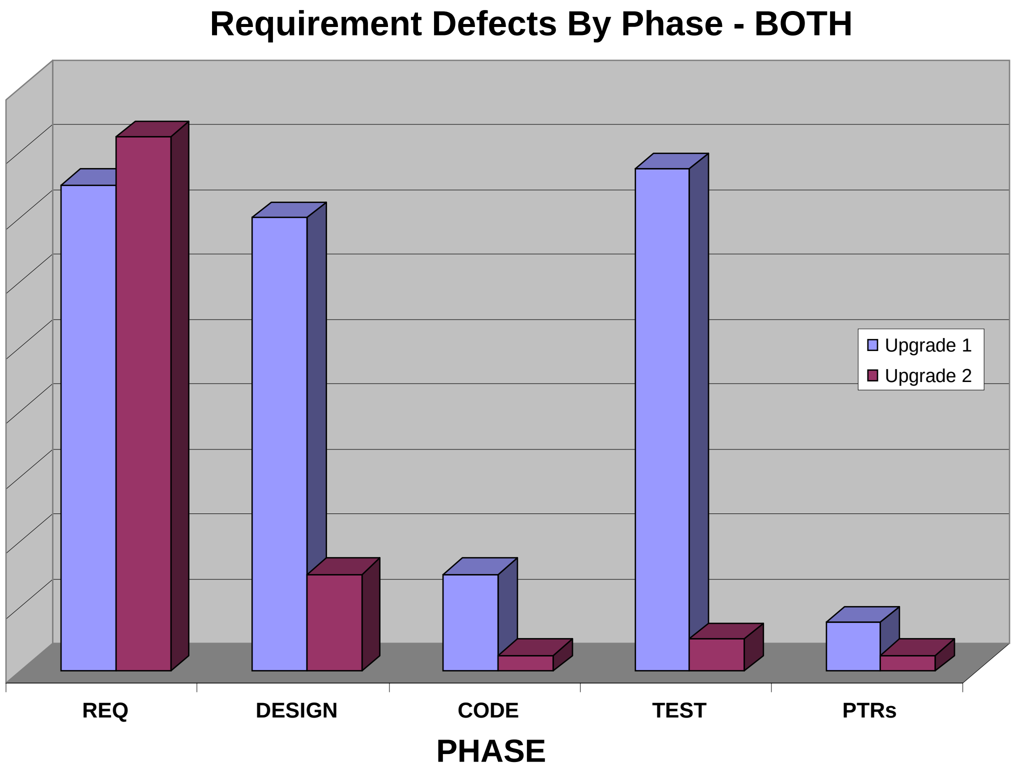
$ Rework caused schedule delays and end product had reduced functionality

$ Defects required multiple updates to s/w system spec

Case Study

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

Upgrade 2 Observations



$ OP-DEMO significantly reduced defects in computer-based Test and post-delivery phases

$ RI significantly reduced defects in Design and Code phases

$ S/W Requirement Spec had a “positive ripple effect” on development

$ Significantly less rework for 2nd upgrade and product was delivered on schedule w/ full functionality

$ Req defects were less severe and were easily fixed

Summary

PROPOSED METHOD TO REDUCE SOFTWARE SYSTEM REQUIREMENT DEFECTS

□ Software system requirement defects can impact cost, schedule, and delivered functionality due to REWORK

□ OP-DEMOS are useful in reducing defects that would be identified during computer-based Test and Deployment phases

□ Requirement Inspections are useful in reducing defects that would be identified during Design & Code phases

□ Improved s/w requirement specifications can cut costs in ALL s/w system development phases, including life-cycle maintenance

□ Combining OP-DEMO and Requirement Inspection is a low-tech approach to reducing s/w requirement defects; is simple to apply and requires minimal training