



Adapting ODC for Empirical Evaluation of Pre-Launch Anomalies

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Topics

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 - **Deep Impact**
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Overview

- **Goal: (1) To characterize pre-launch software anomalies, using data from multiple spacecraft projects, by means of a defect-analysis technology called *Orthogonal Defect Classification (ODC)*.**
(2) To support transfer of ODC to NASA projects through applications and demonstrations.
- **Approach: Analyzed anomaly data using adaptation of *Orthogonal Defect Classification (ODC)* method**
 - Developed at IBM; widely used by industry
 - Quantitative approach
 - Used here to detect patterns in anomaly data
 - More information at <http://www.research.ibm.com/softeng>
- **Adapted ODC for NASA use and applied to NASA projects**



Overview: *Status*

- Previous work used ODC to analyze safety-critical *post-launch* software anomalies on 7 spacecraft.
- FY'03 task extends ODC work to *pre-launch development and testing* (Mars Exploration Rover testing, Deep Impact, contractor-developed software) and to support *technology infusion*
- Plan → Design → Conduct → *Evaluate* → *Use*
- Adapted ODC categories to spacecraft software at JPL:
 - Activity: what was taking place when anomaly occurred?
 - Trigger: what was the catalyst?
 - Target: what was fixed?
 - Type: what kind of fix was done?



Results: *MER*



- **Collaborating with Mars Exploration Rover to experimentally extend ODC approach to *pre-launch software problem/failure testing reports (~600 to date)***
- **Adjusted ODC classifications to testing phases**
- **Institutional defect database → Access database of data of interest → Excel spreadsheet with ODC categories → Pivot tables with multiple views of data**
- **Frequency counts of Activity, Trigger, Target, Type, Trigger within Activity, Type within Target, etc.**
- **User-selectable representation of results support tracking trends and progress:**
 - **Graphical summaries**
 - **Comparisons of testing phases**
- **Provides rapid quantification of data**
- **Project provides feedback/queries on our monthly deliverables of results and on our draft reports/paper**



Results: *Deep Impact*

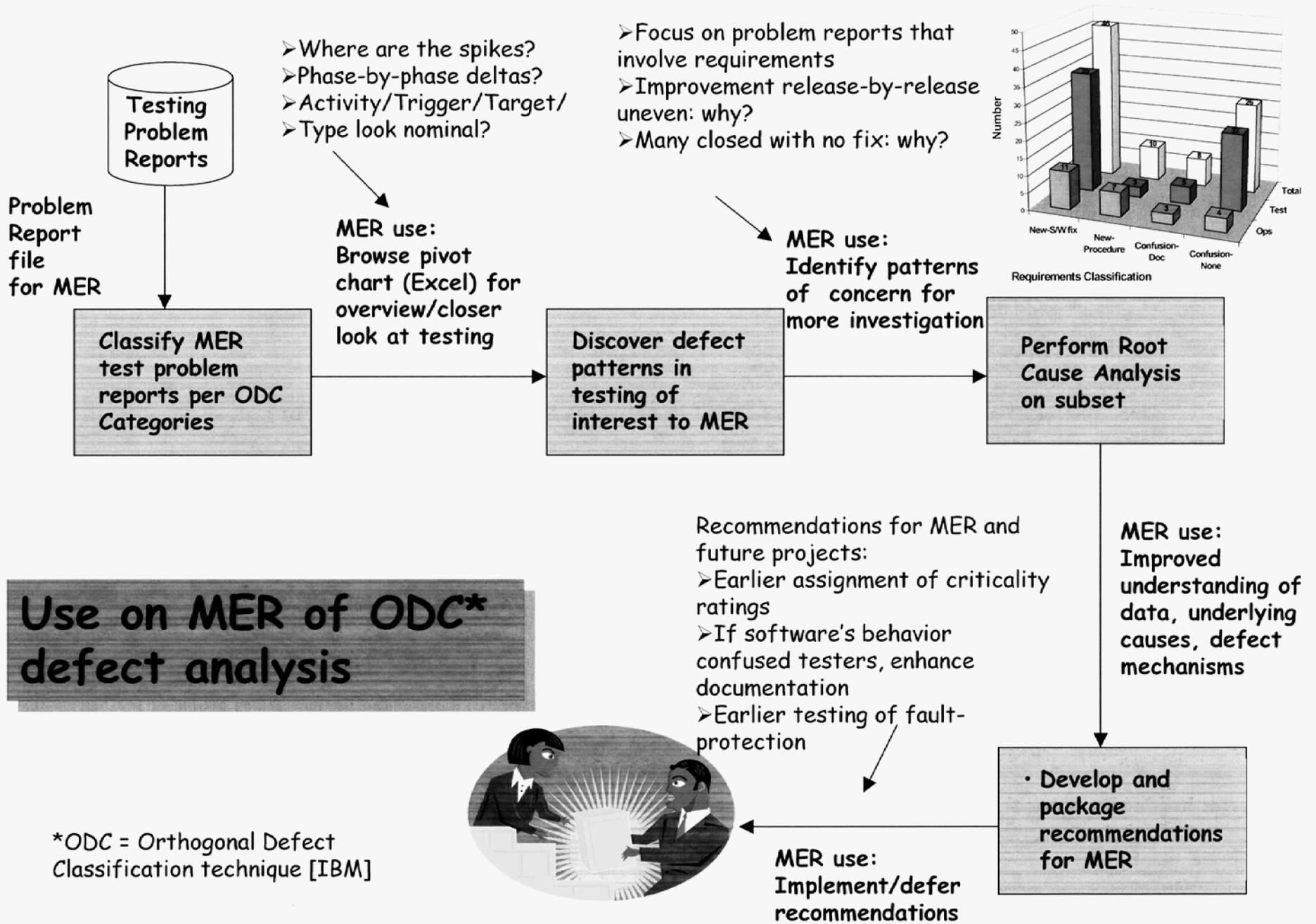
- Collaborating with Deep Impact to extend ODC approach into *software developmental anomaly reports* via ODC classification of development-phase SCRs (Software Change Reports) at Ball
- Classified initial set of 94 critical DI SCRs (with highest cause-corrective action/failure effect ratings)
- Feasibility check: ODC classification of development-stage software defects works well
- Initial delivery to DI of ODC pivot table results (for browsing), of user instructions, and of initial issues/concerns
- Project uses telecons/email to answer questions, suggest paths of interest to project



Results: *Infusion*



- **Gave invited presentation on ODC to JPL's Software Quality Initiative task as candidate defect-analysis tool**
- **Worked with manager/developers of next-generation JPL problem-reporting system to ensure that their web-based database will support projects' choice of ODC**
- **Carmen presented ODC to JPL's DII (Defense Information Infrastructure) project; they requested followup presentation (given); Carmen is working with DII to transition ODC into their operations**
- **Wide distribution of slide summarizing use of ODC on MER (T. Menzies suggestion)**





Results: *Dissemination*

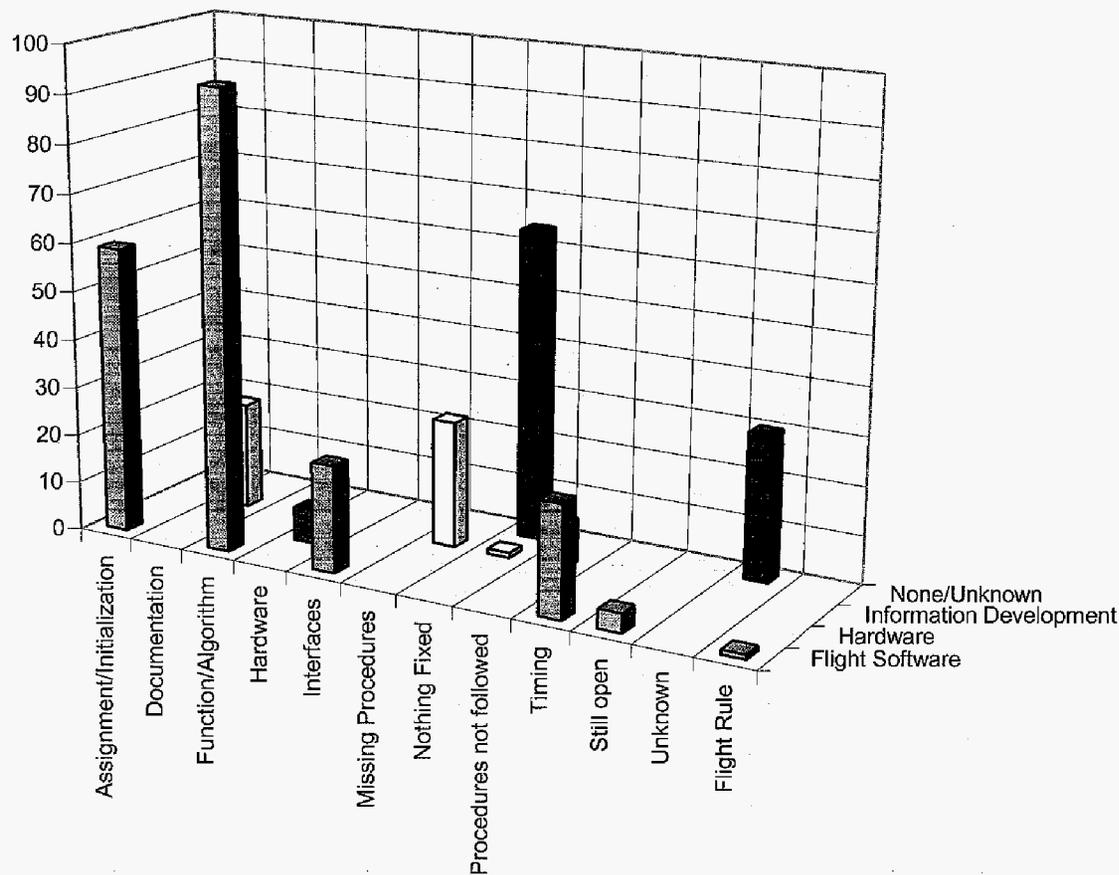
- **Presented paper on the 4 mechanisms involved in requirements discovery during testing at ICSE 2003 (Int'l Conf on S/W Eng)**
- **Presented paper on patterns of defect data at SMC-IT 2003 (Space Mission Challenges)**
- **Presented results at JPL/GSFC QMSW 2003 (Quality Mission Software Workshop)**
- **T. Menzies presented analysis of the ODC defect data at SEKE 2003 (Int'l Conf S/W Eng & Knowledge Eng)**
- **Paper on how operational anomalies drive requirements evolution appeared in Journal of Systems and Software, Feb. 2003**
- **Paper describing similar mechanisms in testing & ops anomalies accepted to RE 2003 (Int'l Requirements Eng Conf); selected as one of best experience papers & paper invited for IEEE Software submission**



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Example: Testing Defect Patterns

Distribution of Types by Target





Example: Lessons Learned from ODC

- **Testing reports give “crystal ball” into operations**
 - **False-positive testing problem reports (where software behavior is correct but unexpected) provide insights into requirements confusions on the part of users**
 - **If software behavior surprised testers, it may surprise operators**
- **Closing problem reports with “No-Fix-Needed” decision can waste opportunity to document /train/ change procedure**
 - **Avoid potentially hazardous recurrence**
 - **Important in long-lived systems with turnover, loss of knowledge**



Benefits

- **Experience: Applied to 9 NASA projects**
 - Development, testing, and operations phases
- **Level of effort affordable**
 - Uses existing fields in existing problem-reporting system)
 - ODC ~ 4 minutes/defect vs. Root cause ~ 19 (Leszak & Perry 2003)
- **Uses metrics information to identify and focus on problem patterns**
 - Incorporates project results into multi-project baseline patterns to provide guidance to future projects
 - Can answer current project's questions regarding defects
- **Flexible**
 - Visualization & browsing options
- **Provides quantitative foundation for process improvement**
- **Equips us with a methodology to continue to learn as projects and processes evolve**



Backup Slides



Sample Defect Patterns Found in Testing

- **2 basic kinds of requirements discovery:**
 - Discovery of new (previously unrecognized) requirements or requirements knowledge
 - Discovery of misunderstandings of (existing) requirements
- **Reflected in ODC Target (what gets fixed) and ODC Type (nature of the fix)**
 - Software change (new requirement allocated to software)
 - Procedural change (new requirement allocated to operational procedure)
 - Document change (requirements confusion addressed via improved documentation)
 - No change needed (works OK as is; user was just confused)



Results

- **2 basic kinds of requirements discovery:**
 - **Discovery of *new* (previously unrecognized) requirements or requirements knowledge**
 - **Discovery of *misunderstandings* of (existing) requirements**
- **Reflected in ODC Target (what gets fixed) and ODC Type (nature of the fix):**
 1. **Software change (new requirement allocated to software)**
 2. **Procedural change (new requirement allocated to operational procedure)**
 3. **Document change (requirements confusion addressed via improved documentation)**
 4. **No change needed**



Results: Examples

1. **Incomplete requirements, resolved by change to software:**

New software requirement became evident: initial state of a component's state machine must wait for the associated motor's initial move to complete

2. **Unexpected requirements interaction, resolved by changes to operational procedures:**

Software fault monitor issued redundant off commands from a particular state (correct but undesirable behavior). Corrective action was to prevent redundant commands procedurally by selecting limits that avoid that state in operations



Results: Examples

3. Requirements confusion, resolved by changes to documentation

Testing personnel incorrectly thought heaters would stay on as software transitioned from pre-separation to Entry/Descent mode; clarified in documentation.

4. Requirements confusion, resolved without change

Testers assumed commands issued when component was off would be rejected, but commands executed upon reboot. No fix needed; behavior correct.