Adapting ODC for Empirical Evaluation of Pre-Launch Anomalies

Dr. Robyn Lutz and Carmen Mikulski

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. The work was sponsored by the NASA Office of Safety and Mission Assurance under the Software Assurance Research Program led by the NASA Software IV&V Facility. This activity is managed locally at JPL through the Assurance and Technology Program Office.

OSMA Software Assurance Symposium
July 29-August 1, 2003
Topics

- Overview
- Results
  - Mars Exploration Rover
  - Deep Impact
  - Infusion of method
  - Dissemination of results
- Examples: Patterns and Lessons Learned
- Benefits
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

- **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 \(\rightarrow\) Access database of data of interest \(\rightarrow\) Excel spreadsheet with ODC categories \(\rightarrow\) 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)
Replacing
Problems
Report
file
for MER

Classify MER test problem reports per ODC Categories

MER use:
Browse pivot chart (Excel) for overview/closer look at testing

Discover defect patterns in testing of interest to MER

Perform Root Cause Analysis on subset

Use on MER of ODC* defect analysis

Recommendations for MER and future projects:
➢ Earlier assignment of criticality ratings
➢ If software's behavior confused testers, enhance documentation
➢ Earlier testing of fault-protection

MER use:
Improved understanding of data, underlying causes, defect mechanisms

➢ Develop and package recommendations for MER

MER use:
Implement/defer recommendations

*ODC = Orthogonal Defect Classification technique [IBM]
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 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
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.