Formalized Pilot Study of Safety-Critical Software Anomalies

Robyn Lutz and Carmen Mikulski (JPL)

NASA Code Q Software Program Center Initiative UPN 323-08; Kenneth McGill, Research Lead

OSMA Software Assurance Symposium

Sept 5-7, 2001

JPL

Topics

- Overview
- Preliminary Results
  - Quantitative analysis
  - Evolution of requirements
  - Visualization tools
- Work-in-progress
- Benefits

Overview: *Goal*

To reduce the number of safety-critical software anomalies that occur during flight by providing a *quantitative analysis* of previous anomalies as a foundation for process improvement.

Overview: *Approach*

- Analyzed anomaly data using *Orthogonal Defect Classification (ODC)* method
  - Developed at IBM; widely used by industry
  - Quantitative approach
  - Used here to detect patterns in anomaly data
- Evaluated ODC using *Formalized Pilot Study*
  - R. Glass ['97] detailed rigorous process to get valid results
  - 35 steps divided into 5 phases
  - Used here to evaluate ODC for NASA use

Overview: *Status*

- Year 2 of planned 3-year study

  Plan → Design → Conduct → *Evaluate* → Use
- Adapted ODC categories to operational spacecraft software:
  - Activity: what was taking place when anomaly occurred?
  - Trigger: what was the catalyst?
  - Target: what was fixed?
  - Type: what kind of fix was done?

Preliminary Results: *Quantitative Analysis*

- **Analyzed 189 Incident/Surprise/Anomaly reports (ISAs) of highest criticality**
  - **7 spacecraft: Cassini, Deep Space 1, Mars Global Surveyor, Galileo, Mars Polar Lander, Mars Climate Orbiter, Stardust**
- **Institutional defect database → Access database of data of interest → Excel spreadsheet with ODC categories → Pivot tables with multiple views of data**
- **1-D and 2-D frequency counts of Activity, Trigger, Target, Type, Trigger within Activity, Type within Target, etc.**

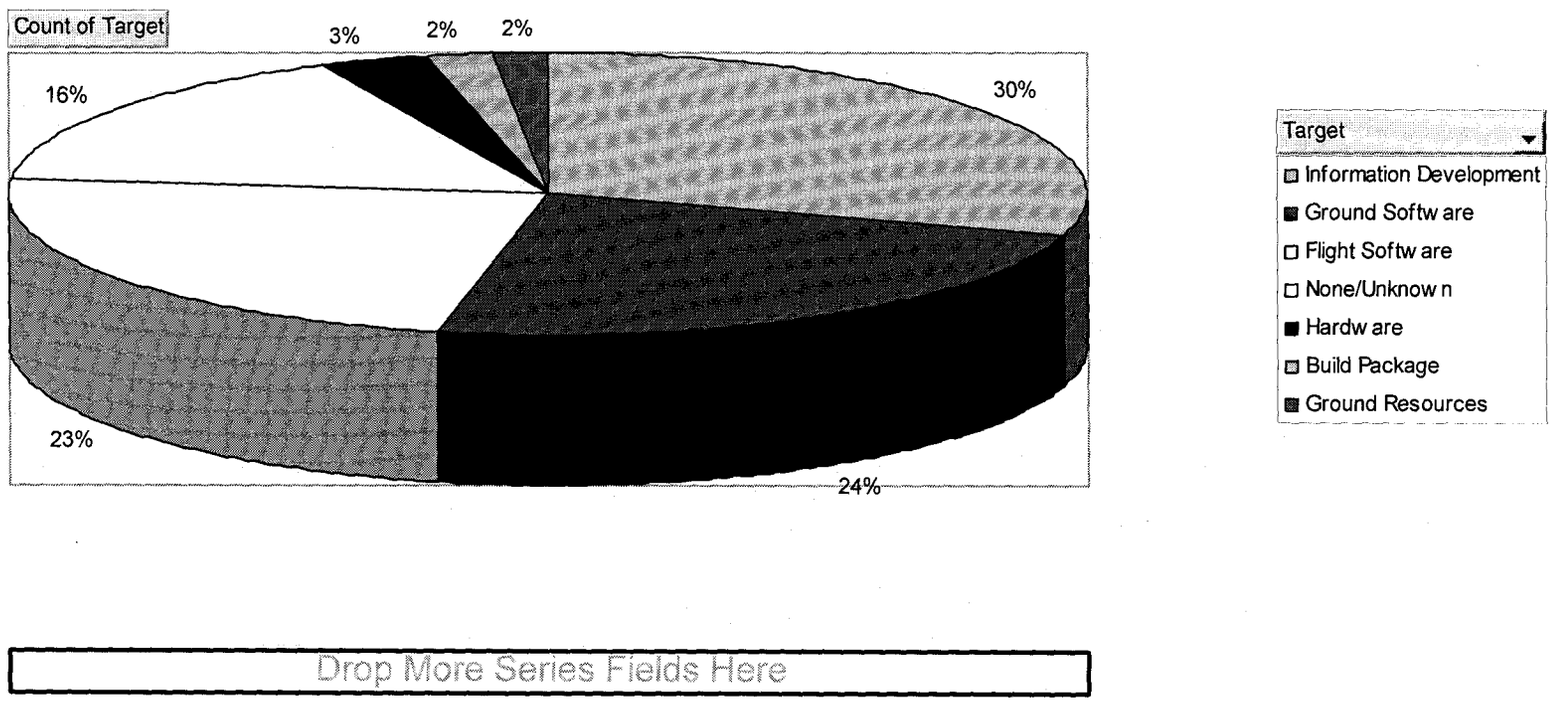
Preliminary Results: *Quantitative Analysis*

- User-selectable representation of analysis results: tables, pie charts, bar graphs
- User-selectable sets of spacecraft for comparisons
- Provides rapid quantification of data
- Assists in detecting unexpected patterns, confirming expected patterns

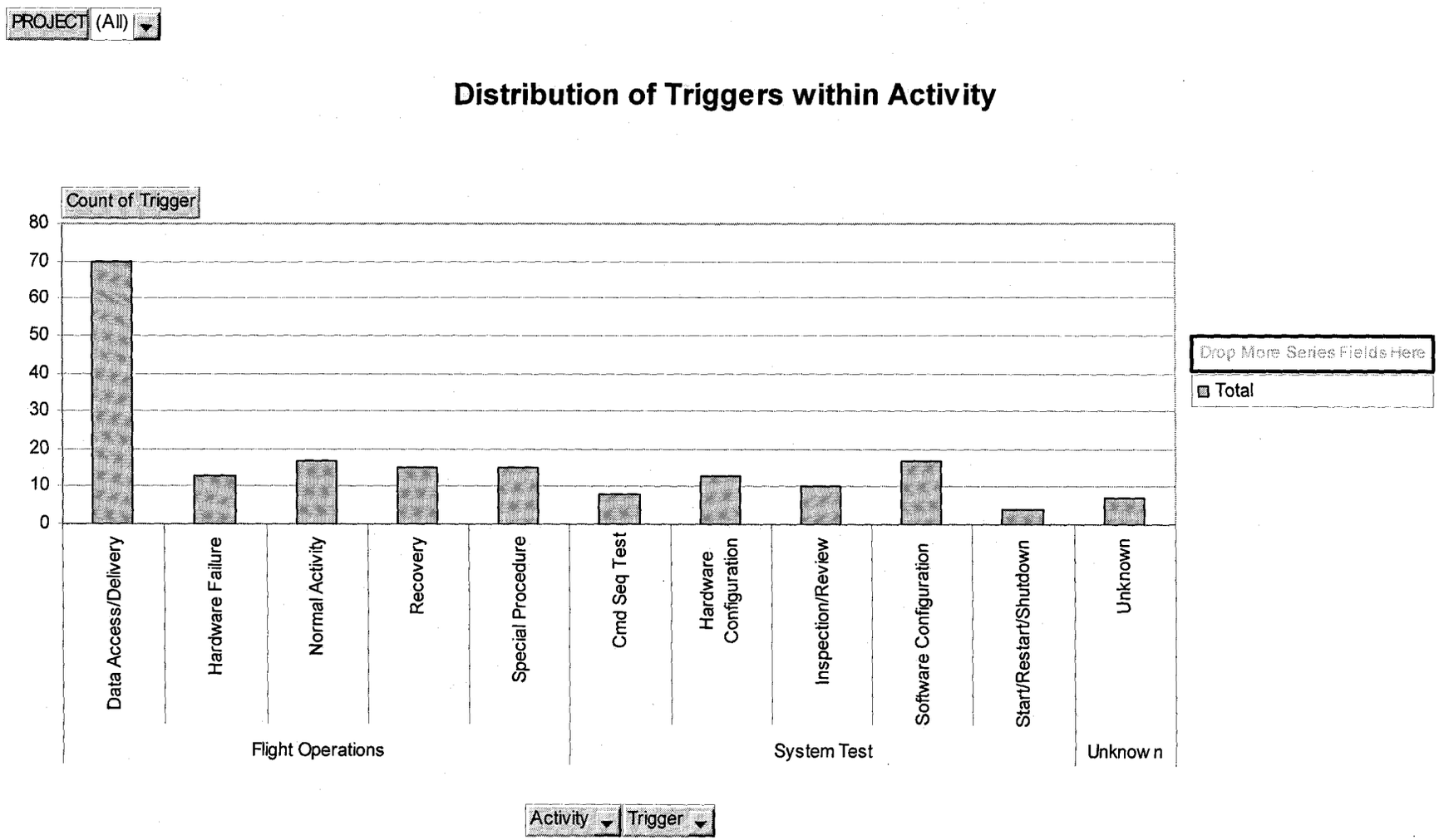
Preliminary Results: *Quantitative Analysis*

PROJECT (All)

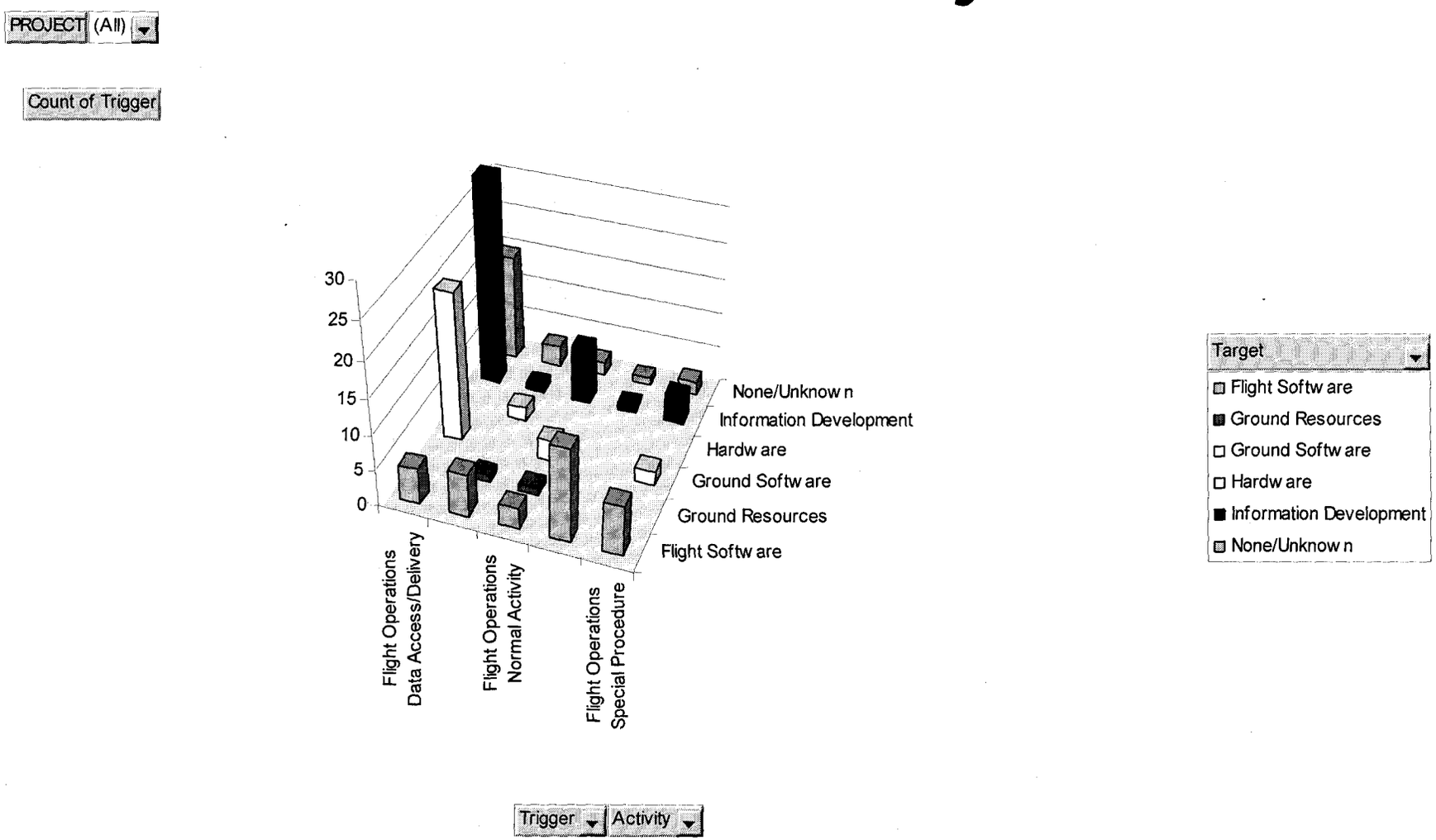
Target Distribution



Preliminary Results: *Quantitative Analysis*



Preliminary Results:
Quantitative Analysis



Preliminary Results:
Evolution of Safety-Critical Requirements Post-Launch

- **Anomalies sometimes result in changes to software requirements**
  - **Looked at 86 critical ISAs from 3 spacecraft (MGS, DS-1, Cassini)**
  - **17 of 86 had Target (what was fixed) = Flight Software**
  - **8 of 17 changed code only; 1 was incorrect patch; 1 used contingency command**
  - **Focused on remaining 7 with *new software requirements* as a result of critical anomaly**

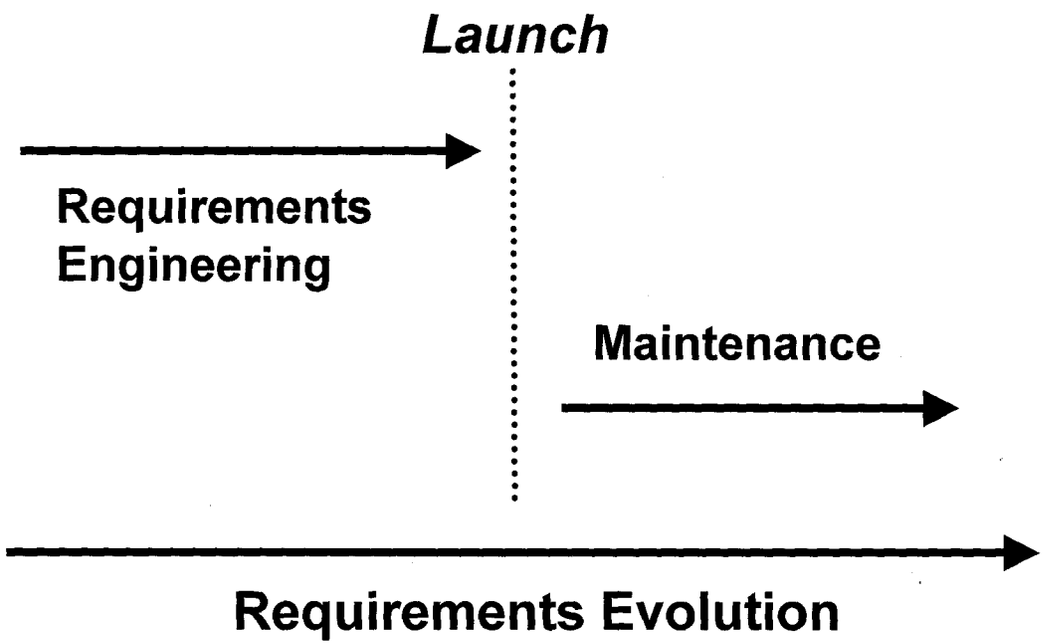
Preliminary Results:
Evolution of Safety-Critical Requirements Post-Launch

- Found that requirements changes are *not* due to earlier requirement errors
- Instead, requirements changes are due to:
  - Need to handle rare event or scenario (4; software adds fault tolerance)
  - Need to compensate for hardware failure or limitations (3; software adds robustness)

Preliminary Results:
Evolution of Safety-Critical Requirements Post-Launch

- **Confirms value of requirements completeness for fault tolerance**
- **Confirms value of contingency planning to speed change**
- **Contradicts assumption that "what breaks is what gets fixed"**
- **Suggests need for better requirements engineering for maintenance**
- **Results presented at IFIP WG 2.9 Workshop on Requirements Engineering, Feb, 2001; 5th IEEE International Symposium on Requirements Engineering, Aug, 2001.**

Preliminary Results:
Evolution of Safety-Critical Requirements Post-Launch



Preliminary Results: *Web-based Visualization Tool*

- Results of Peter Neubauer (ASU), Caltech/JPL Summer Undergraduate Research Fellow, 2001
- Developed alternate visualizations of data results to support users' analyses
- Web-based tool assists distributed users
- Sophisticated tool architecture builds on existing freeware
- Demo at QA Section Manager's meeting (FAQ: Would this work for our project?)
- Demo to D. Potter's JPL group developing next-generation Failure Anomaly Management System

Preliminary Results:
Web-based Visualization Tool

*Objective: Investigate and characterize the common causes of **safety-critical, in-flight software anomalies** on spacecraft. The work uses a defect-analysis technology called Orthogonal Defect Classification, developed at IBM. A rigorous pilot study approach using the Glass criteria is currently underway.*

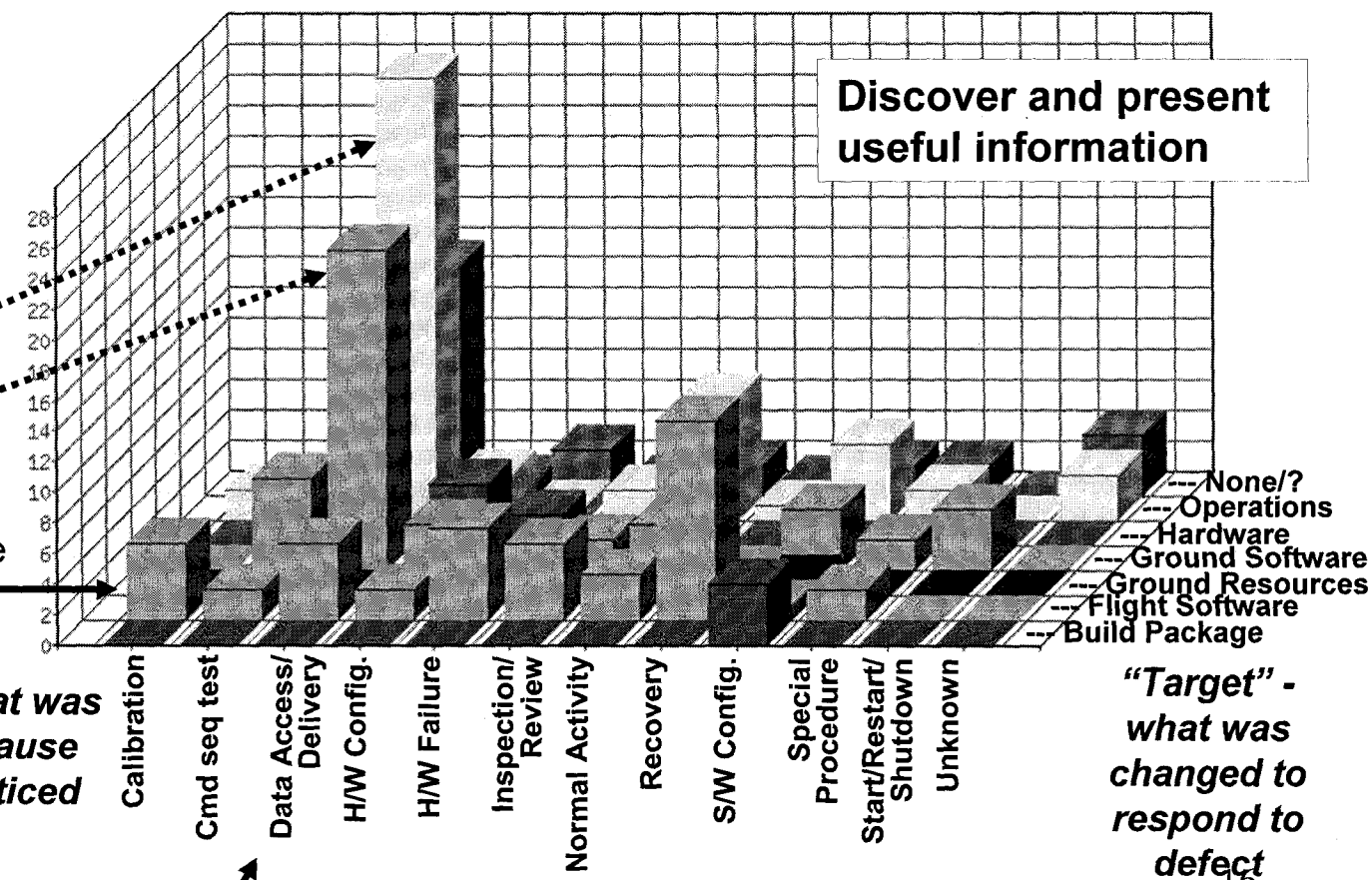
7 space missions: 189 defects classified; chart shows one of the 6 possible 2-way views into this information

Large number of defects seen during sending commands to / receiving data from spacecraft.

Of these, many were responded to by changing operational procedures or software on the ground.

For other defects, changes to flight software more prevalent

Discover and present useful information



"Trigger" – what was happening to cause defect to be noticed

"Target" - what was changed to respond to defect

Work-in-progress

- Several patterns noted but not yet quantified
  - Ex: Procedures often implicated
- Profile by mission phase
  - Ex: Cruise, orbit insertion, entry, landing
- Better way to disseminate "mini-LL's"?
  - Ex: Corrective action sometimes notes need for similar action on a future mission
- Incorporate standardized ODC classifications in next-generation database to support automation and visualization

Benefits

- Data mining of historical and current databases of incidents / surprises / anomalies
- Uses metrics information to identify and focus on problem areas
- Provides a quantitative foundation for process improvement
- Equips us with a methodology to continue to learn as projects and processes evolve