JPL Test Effectiveness Analysis

Authors: Stephanie Shreck, Stephen Sharratt, Joseph F. Smith,
Jet Propulsion Laboratory, Pasadena, CA USA
California Institute of Technology
Edward Strong
Johnson Space Center, Houston, TX USA

Presentor: JPL Reliability Engineering Representative

24th Aerospace Testing Seminar
Manhattan Beach, CA USA
April 8-10, 2008

CONSTELLATION

Topics

- **Background**
- **Pilot Study Approach**
- **Representative Studies-Overview**
- **Pilot Study Examples**
  - Environmental Test Effectiveness at System Level
    - Mission and Subsystem
  - Problem Failure Cause at System level
    - Mission and Subsystem
  - Use of Ground testing to Reduce In-Flight Anomalies
    - Mission and Subsystem
- **Pilot Study Conclusions**

Background

- **Constellation (Cx) Program designing and fabricating several vehicles and systems**
  - CX Test and Verification program required to ensure hardware and software safe, reliable, and qualified for human space flight

- **Major objective of Test Effectiveness Pilot Study**
  - Develop and validate methodology to be used by Cx program to collect and analyze appropriate data (historical and current) so that prelaunch test and verifcation efforts will minimize in-flight failures and anomalies

Pilot Study Approach

- **Acquire data from JPL mission databases**
  - Use current JPL databases for problem/failure reports (PFR) and incidents, surprises, and anomalies (ISA)
  - Examine eleven (11) unmanned space mission programs
- **Systematically classify problems/failures/incidents by correlating with prescribed set of attributes including:**
  - Mission Phase-Development (ie Prelaunch) or in-flight operations
  - Prelaunch tests-Performance at subsystem or system level
  - Prelaunch tests-Environmental at subsystem or system level
  - Cause-Design, manufacturing & workmanship, and parts issues
- **Perform high level assessments**
  - Repeat and update four of the older ('92 to '94) Test Effectiveness studies with new set of missions
- **Develop pilot study conclusions and lessons learned**

Representative Studies-Overview

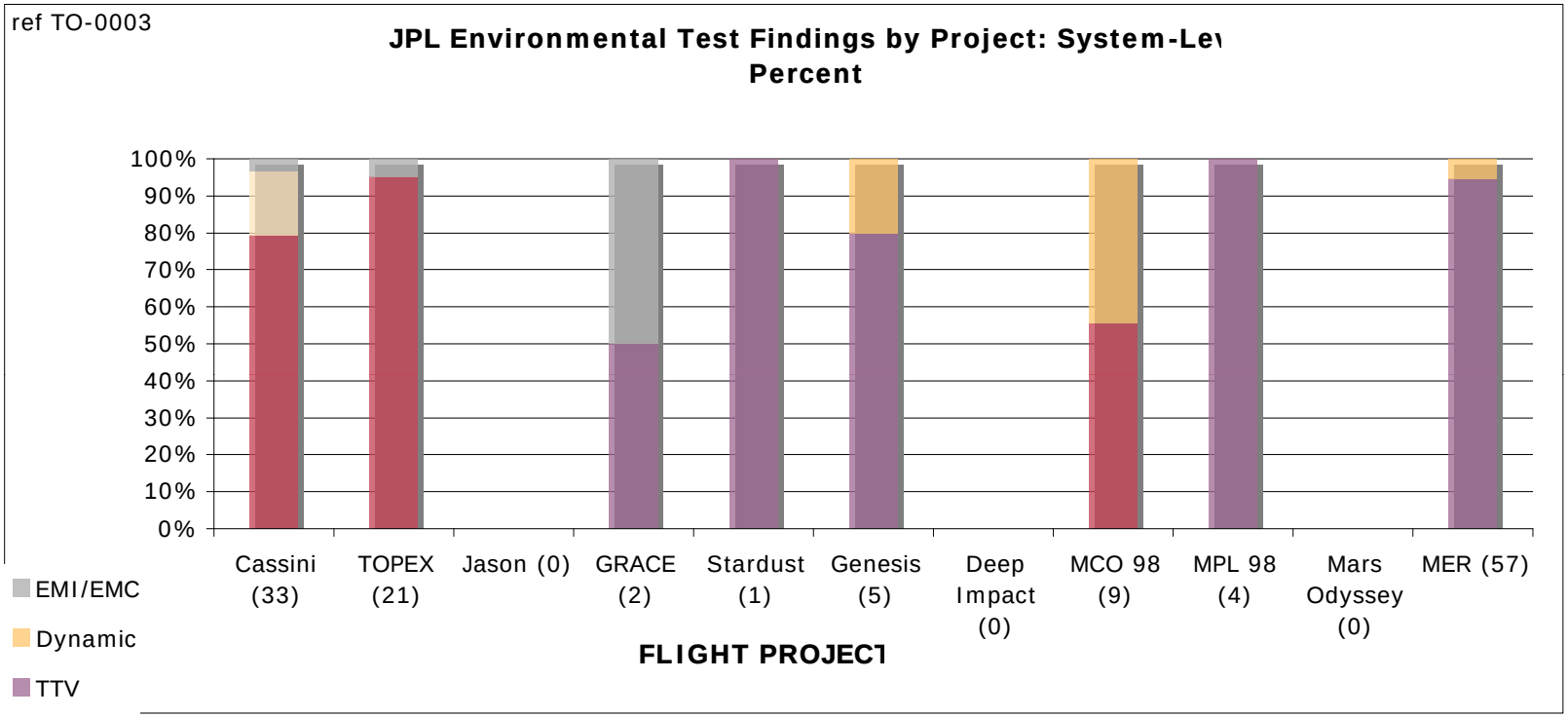
- **TO-0003: Environmental Test Effectiveness as Indicated Mission Anomalies**
  - Considers which environmental-test environments are most effective in screening out problems
- **TO-0008: Problem/Failure Cause**
  - Compares the number of problems/failures uncovered during testing of spaceflight hardware caused by design problems, manufacturing/workmanship, and parts failures
- **TO-0021: The Use of Ground Testing to Reduce Potential In-Flight Anomalies**
  - Discusses the effectiveness of ground testing of flight hardware in reducing in-flight anomalies as evidenced by the type of anomalies that occur in-flight

More study needed for following (Database not sufficient)

- **TO-0001: Powered-On Assembly Level Vibration Testing**
  - Demonstrates why power on is a necessary condition during vibration testing to uncover electrical problems

Pilot Study Example

Environmental Test Effectiveness at the System Level, by Mission

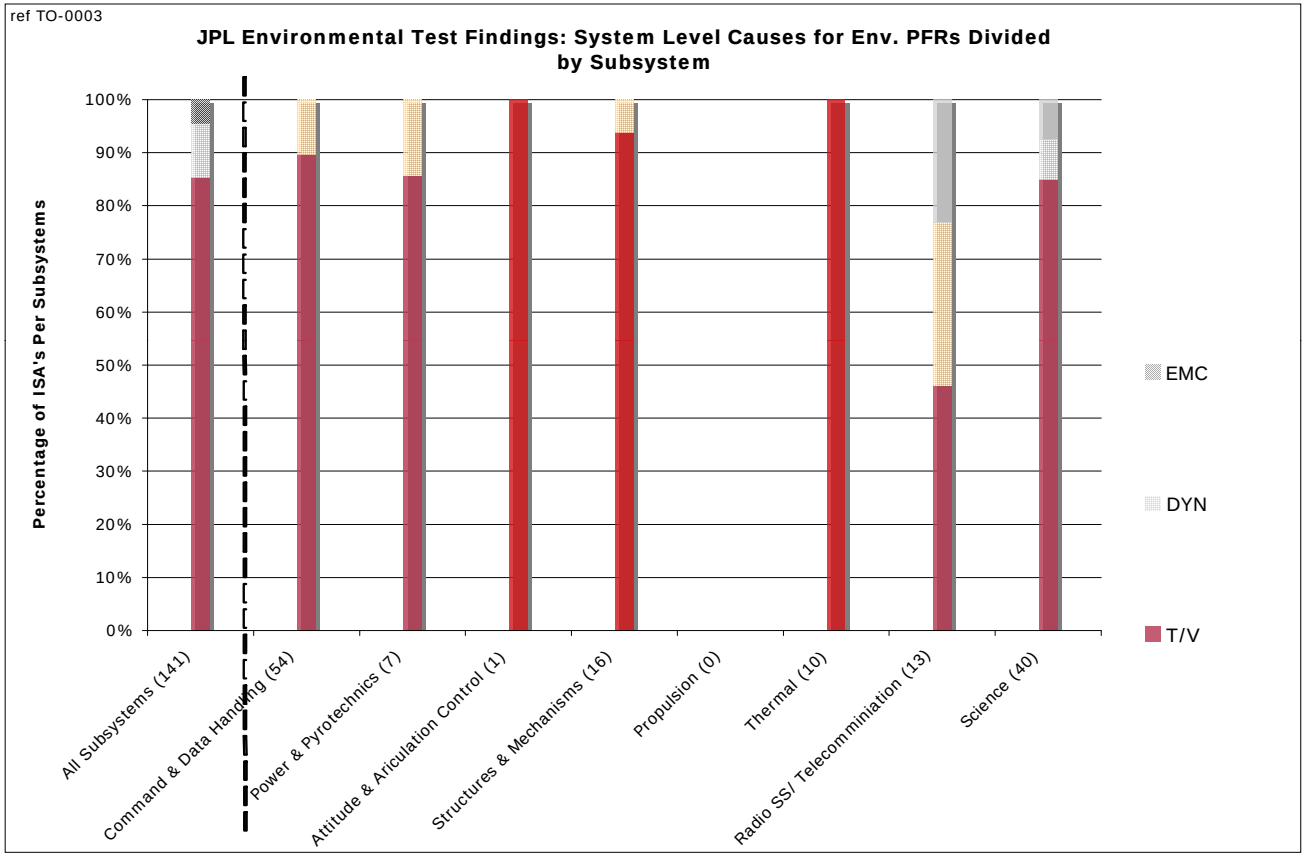


- **All missions except GRACE had more thermal/ thermal vac anomalies than other types of environmental test anomalies**

- *Note: not all missions recorded environmental test anomalies at the system level*

Pilot Study Example

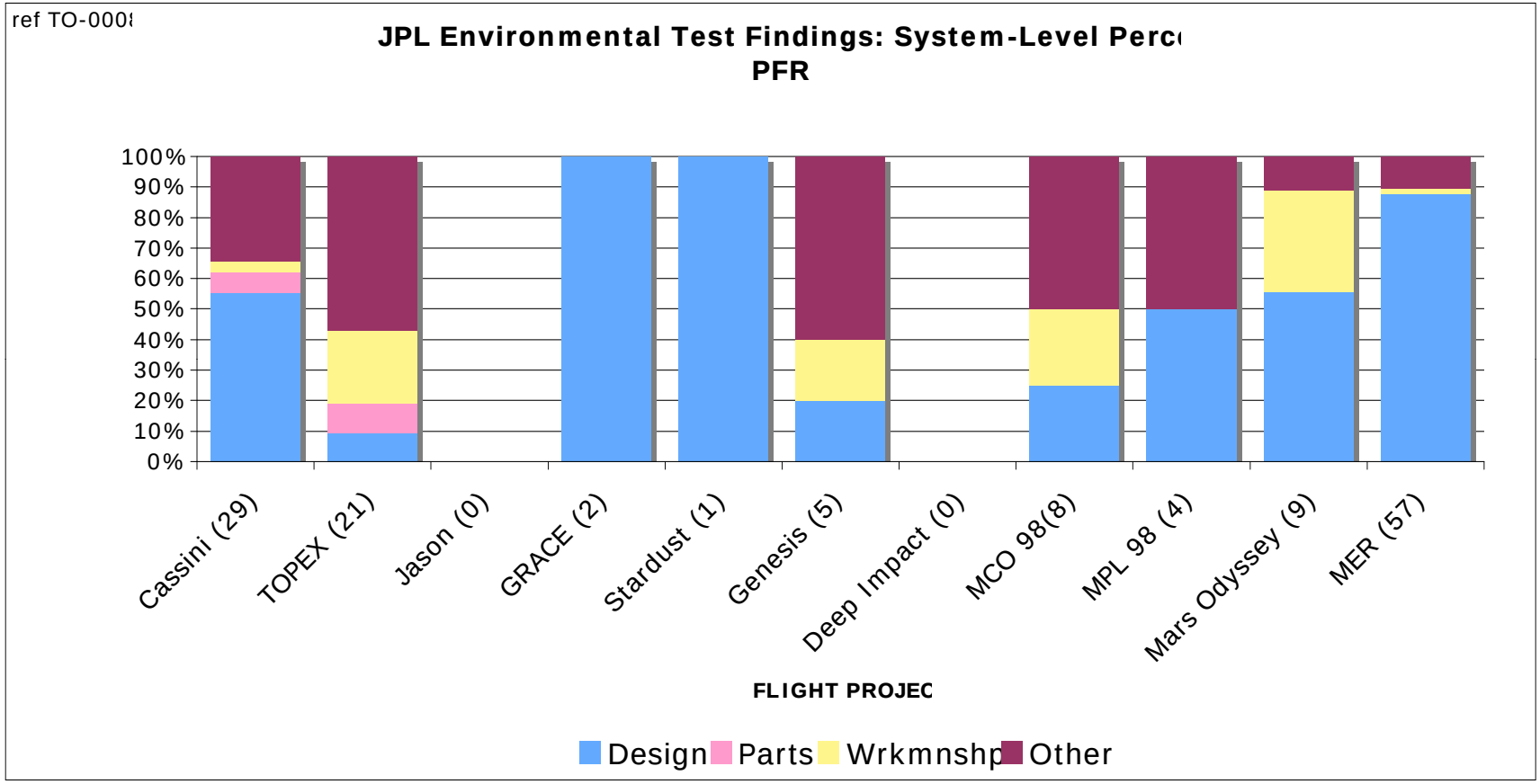
Environmental Test Effectiveness at the System Level, by Subsystem



- **Thermal/Thermal Vac tests are dominate (>80%) in their ability to find system level anomalies for all subsystems, except for Telecom**

Pilot Study Example

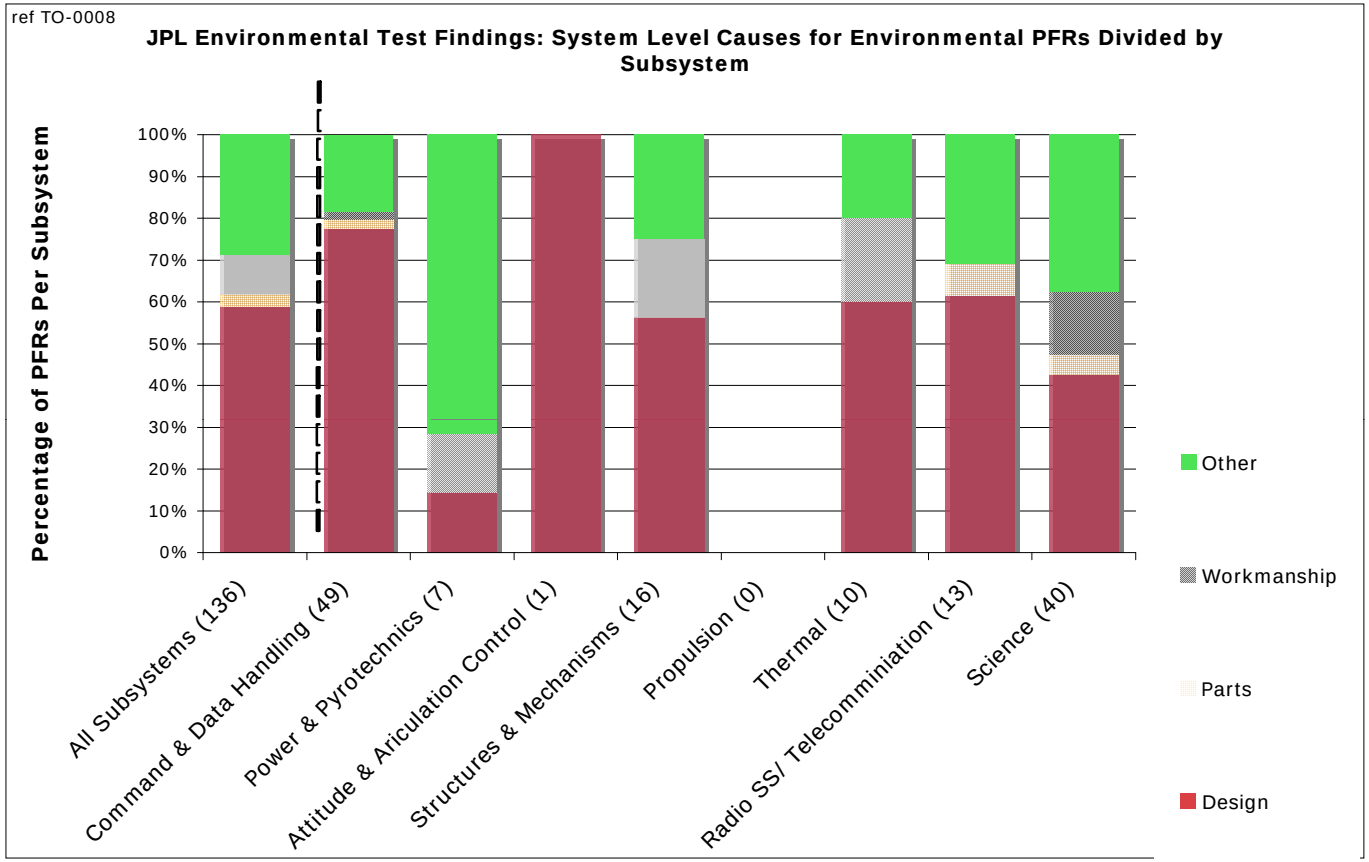
Problem/ Failure Cause at the System Level, by Mission



- At the System level, there is no clear type of anomaly cause evident
- May not have enough problem reports (cases) in the data base to draw any conclusions
- Of newer missions, only Cassini, TOPEX, and MER have more than a few problem reports at this level

Pilot Study Example

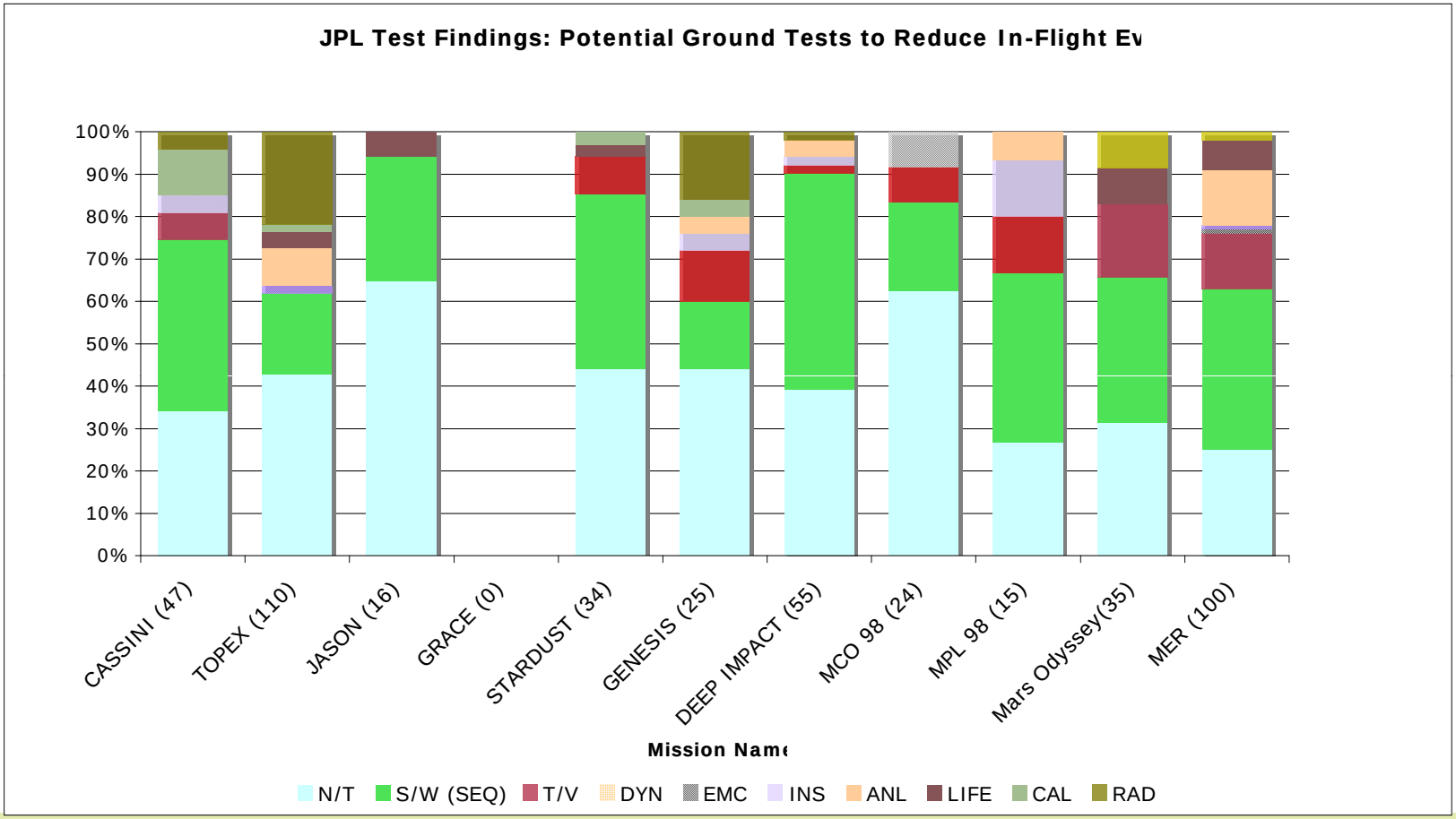
Problem/ Failure Cause at the System Level, by Subsystem



- **At the system level, design is the most important cause of problems/ failures, representing 59% of all subsystem failures**

Pilot Study Example

Use of Ground Testing to Reduce In-Flight Anomalies by Mission

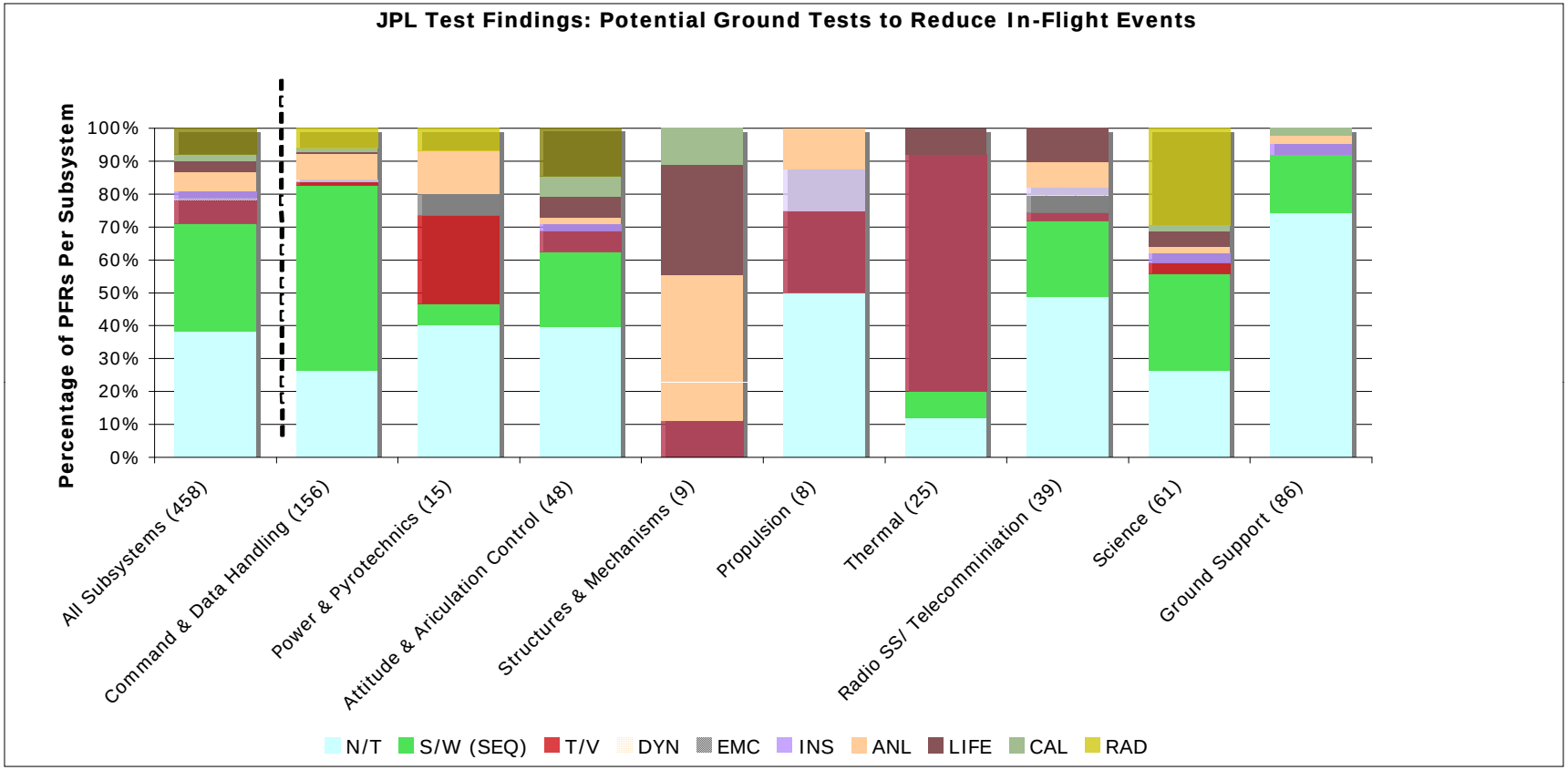


- **Environmental and functional tests would have caught the majority of in-flight anomalies for all but two (2) missions.**
  - Software dominated the in-flight failures in the environmental and functional test categories.
  - Additional environmental testing (TV, EMC, radiation) could have helped reduce the remaining system level flight anomalies for these missions.

Note: For the largest anomaly category (blue category), no environmental test could have stopped the flight anomaly from occurring (e.g., incorrect design requirements)

Pilot Study Example

Use of Ground Testing to Reduce In-Flight Anomalies by Subsystem



- **Environmental and functional tests would have caught the majority of in-flight anomalies for all but 1 subsystem.**
  - The effectiveness of pre-launch testing on in-flight anomalies varies significantly between different subsystems, and should be considered on a subsystem-by-subsystem basis

Note: For the largest anomaly category (blue category), no environmental test could have stopped the flight anomaly from occurring (e.g., incorrect design requirements)

JPL Pilot Study Conclusions and Lessons Learned

- **The pilot study provided meaningful conclusions that are generally consistent with the earlier Test Effectiveness work done between 1992 and 1994**
  - Analysis of pre-launch problem/failure reports is consistent with earlier work
  - Analysis of post-launch early mission anomaly reports indicates that there are more software issues in newer missions, and the “no-test” category for identification of post-launch failures is more significant than in the earlier analysis
- **Future work includes understanding how differences in Missions effect these analyses**
  - There are large variations in the number of problem reports and issues that are documented by the different Projects/Missions
  - Some missions do not have any reported environmental test anomalies, even though environmental tests were performed
- **Each project/mission has different standards and conventions for filling out the PFR forms, the industry may wish to address this issue**
  - Existing problem reporting forms are to document and track problems, failures, and issues (etc.) for the projects, to ensure high quality
  - Existing problem reporting forms are not intended for data mining

Acknowledgements

- **Study Authors:**
  - Stephanie Shreck: University of Minnesota, Twin Cities, Minneapolis, MN (formerly of JPL/Caltech)
  - Stephen Sharratt: University of California Los Angeles, Los Angeles, CA (formerly of JPL/Caltech)
  - Joseph F. Smith: Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA
  - Edward Strong: NASA Johnson Space Center, Houston, TX
- **Also instrumental to this Task: Pamela Chadbourne, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA**
- **Other involved in this task:**
  - Richard Beatty, Leslie Callum, Kelly Clarke, Debbie Cowan, Christine Farguson, Janis Graham, Casey Heeg, Glenn Johnson, Gail Klein, Kin Fung Man, William Moore, Craig Peterson, Jack Quinn, and Joseph Skipper
  - Special thanks to Alan Hoffman for his expert assistance
  - These people are from the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA