Session 1
Verification and Testing Standards/Test Quality

Title
JET PROPULSION LABORATORY
ENVIRONMENTAL TEST STANDARDS
AN OVERVIEW
A. Hoffman, K. Evans, T. Fisher, J. Forgrave

Speaker: John Forgrave
Jet Propulsion Laboratory
California Institute of Technology
Topics

- Background
  - JPL Design Principles
  - JPL Flight Project Practices
- Environmental Design and Verification
- Environmental Program Flow
- Environmental Verification Summary
- Environmental Design and Test Margins
- Issues to be Addressed at Workshop
- Summary
JPL Environmental Testing Standards

- **Design Principles**
  - Capture institutional standards for designing, verifying, validating, and operating flight systems

- **Flight Project Practices**
  - Establish standards of uniformity, where standardization is judged to have significant benefit
  - Capture approaches and methods important to sponsors
  - Incorporate lessons learned that were key to past successes, and where deviations created significant problems
  - Require management review and approval to waive
JPL Environmental Testing Standards (Cont.)

• **Flight Project Practices (Cont.)**
  • 6.13 Design and Verification for Environmental Compatibility
    • Flight hardware designed and verified to be fully compatible with all anticipated environments.
    • System level environmental test program: modal, static, random vibration, acoustic, thermal, EMI/EMC and pyroshock
    • Assembly/subsystem level environmental test program: random vibration, acoustic, thermal pyroshock, EMC, and atmospheric
JPL Environmental Testing Standards (Cont.)
Flight Project Practices (Cont.)

• 6.13 Design and Verification for Environmental Compatibility (Cont.)
  • Test Authorization: project approved and certified
  • Test Execution: approved procedures
    qualification and flight acceptance testing
    - Protoflight testing all flight articles
    - Qualification testing one flight unit followed by flight acceptance testing all other flight units

• Test Configuration
  • All hardware environmentally tested before system level environmental tests
  • System level environmental tests include full complement of flight hardware
JPL Environmental Testing Standards (Cont.)
Flight Project Practices (Cont.)

• 6.13 Design and Verification for Environmental Compatibility (Cont.)
  • Post-Test Documentation: Test results documented including exceptions
  • Test Certification-Review of test objectives and requirements satisfied by project
JPL Environmental Testing Standards (Cont.)
Flight Project Practices (Cont.)
• 6.13 Design and Verification for Environmental Compatibility (Cont.)
  • Document Standards (ie implement this Flight Project Practice)
  • Spacecraft System Dynamic and Static Testing
  • System Thermal Testing
  • Assembly and Subsystem Level Environmental Verification
**Typical Environmental Program Flow**

1. Parts Program
2. Environmental Program
3. Packaging Program

Environmental Requirements Document (Includes Test & Analysis Matrix)

Environmental Verification Specification

Analysis per Test & Analysis Matrix

Nonradiation Analysis

- EACS: Environmental Analysis Completion Statement

- Analysis Review & Approval

Radiation Analysis

- RACS: Radiation Analysis Completion Statement

- Test Authorization

  - Authorization Review & Approval

  - Detailed Test Plan/Procedures

  - Define Retest Requirements
    - No
    - Pass Test?
      - Yes
      - Test Reporting
      - Test Review & Approval

- Environmental Test

- Deliver Hardware
### Typical Environmental Verification Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Environment</th>
<th>Assembly</th>
<th>Spacecraft</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test (T)</strong></td>
<td>Dynamics</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Thermal</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Electromagnetic Compatibility</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Magnetics</td>
<td>T</td>
<td>A</td>
</tr>
<tr>
<td><strong>Analysis (A)</strong></td>
<td>Electrostatic Discharge</td>
<td>A</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Radiation</td>
<td>A</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Solid Particles</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Atomic Oxygen</td>
<td>A</td>
<td>—</td>
</tr>
</tbody>
</table>
## TYPICAL TEST REQUIREMENTS AND MARGINS

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Flight Acceptance</th>
<th>Assembly</th>
<th>Qualification</th>
<th>Spacecraft System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustics Amplitude</td>
<td>MEFL</td>
<td>MEFL + 3dB</td>
<td>MEFL + 3dB</td>
<td>MEFL + 3dB</td>
</tr>
<tr>
<td>Acoustics Duration</td>
<td>1 min</td>
<td>1 min</td>
<td>2 min</td>
<td>1 min</td>
</tr>
<tr>
<td>Random Vibration Amplitude</td>
<td>MEFL</td>
<td>MEFL + 3dB</td>
<td>MEFL + 3dB</td>
<td>NO TEST</td>
</tr>
<tr>
<td>Random Vibration Duration</td>
<td>1 min/AXIS</td>
<td>1 min/AXIS</td>
<td>2 min/AXIS</td>
<td></td>
</tr>
<tr>
<td>Pyro Shock</td>
<td>NONE</td>
<td>MEFL + 3dB</td>
<td>MEFL + 3dB</td>
<td>1 actual device firings</td>
</tr>
<tr>
<td></td>
<td>1 shock/AXIS</td>
<td>3 shocks/AXIS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Torino 18/19 March 2003
<table>
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<th>Assembly</th>
<th>Qualification</th>
<th>Spacecraft System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flight Acceptance</td>
<td>Protoflight</td>
<td>Qualification</td>
</tr>
<tr>
<td>Temperature</td>
<td>Allow Flt + 5°C</td>
<td>-35 to 75°C or Allow Flt +20°C - 15°C</td>
<td>-35 to 75°C or Allow Flt +20°C - 15°C</td>
</tr>
<tr>
<td>Pressure Profile</td>
<td>None</td>
<td>1.5 X MAX dP/dt</td>
<td>1.5 X MAX dP/dt</td>
</tr>
<tr>
<td>EMC</td>
<td>None (grounding/isolation only)</td>
<td>MEFL + 6 dB Freq. Dependent Margin &gt; 60 dB</td>
<td>MEFL + 6 dB Freq. Dependent Margin &gt; 60 dB</td>
</tr>
<tr>
<td>RF Susceptibility</td>
<td>None</td>
<td>MEFL - 6 dB Freq. Dependent</td>
<td>MEFL - 6 dB Freq. Dependent</td>
</tr>
<tr>
<td>Emissions</td>
<td>None (grounding/isolation only)</td>
<td>MEFL - 6 dB Freq. Dependent</td>
<td>MEFL - 6 dB Freq. Dependent</td>
</tr>
</tbody>
</table>
Issues to be Addressed at workshop

- Terminology
  - Hardware Hierarchy
  - Environmental Program Definitions
    - Qualification
    - Flight Acceptance
    - Protoflight
- Test Margins and Rationale
- Post-Test Documentation
  - Assembly Level
  - Systems Level
- Qualification by Similarity
Summary

- Environmental Design and Verification Standards for flight systems have been evolving at JPL and other NASA centers for the last 40 years.
  - JPL documenting in institutional standards imbedded in Flight Project Practices

- System level environmental test program: modal, static, random vibration, acoustic, thermal, EMI/EMC and pyroshock

- Assembly/subsystem level environmental test program: random vibration, acoustic, thermal, pyroshock, EMC, and atmospheric
Assure Product Reliability
Hardware Terminology

<table>
<thead>
<tr>
<th>TERMINOLOGY</th>
<th>JPL</th>
<th>GSFC</th>
<th>EUROPEAN</th>
<th>OTHER TERMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piecepart</td>
<td>Part</td>
<td></td>
<td></td>
<td>component, element</td>
</tr>
<tr>
<td>Subass' y</td>
<td>Assembly(?)</td>
<td>pwr &amp; gyro</td>
<td></td>
<td>component, slice, tray, unit, element, blackbox</td>
</tr>
<tr>
<td>Assembly</td>
<td>component, unit, section (testable level)</td>
<td></td>
<td></td>
<td>unit, element, blackbox, instrument</td>
</tr>
<tr>
<td>Subsystem</td>
<td>Subsystem, instrument, module, structural assembly</td>
<td></td>
<td></td>
<td>unit, element, blackbox, instrument, system</td>
</tr>
<tr>
<td>System</td>
<td>Payload = spacecraft, laboratory, observatory, satellite</td>
<td>spacecraft</td>
<td></td>
<td>spacecraft, instrument, subsystem</td>
</tr>
</tbody>
</table>

Suggestions: s/c system, (engineering++payload) instrument system - single instrument payload system - group of instruments

Issue: 1) slice, tray, synonymous with subassembly 2) define assembly levels up-front in doc list

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