Environmental Verification Standards for Space Hardware

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Topics

- Background
  - JPL Design Principles
  - JPL Flight Project Practices
- Environmental Design and Verification
- Environmental Program Flow
- Environmental Verification Summary
- Environmental Design and Test Margins
- 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

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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

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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

*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

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**TYPICAL TEST REQUIREMENTS AND MARGINS**

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Flight Acceptance</th>
<th>Protoflight</th>
<th>Qualification</th>
<th>Protoflight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustics</td>
<td>MEFL</td>
<td>MEFL + 3dB</td>
<td>MEFL + 3dB</td>
<td>MEFL + 3dB</td>
</tr>
<tr>
<td>Amplitude</td>
<td>1 min</td>
<td>1 min</td>
<td>2 min</td>
<td>1 min</td>
</tr>
<tr>
<td>Duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random Vibration</td>
<td>MEFL</td>
<td>MEFL + 3dB</td>
<td>MEFL + 3dB</td>
<td>MEFL + 3dB</td>
</tr>
<tr>
<td>Amplitude</td>
<td>1 min/AXIS</td>
<td>1 min/AXIS</td>
<td>2 min/AXIS</td>
<td>1 min</td>
</tr>
<tr>
<td>Duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyro Shock</td>
<td>NONE</td>
<td>MEFL + 3dB</td>
<td>MEFL + 3dB</td>
<td>2 firings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 shock/AXIS</td>
<td>2 shocks/AXIS</td>
<td>(dominant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>shock sources)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 firing (other sources)</td>
</tr>
</tbody>
</table>

MEFL: Maximum Expected Flight Level

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### TYPICAL TEST REQUIREMENTS AND MARGINS (CONT.)

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Flight Acceptance</th>
<th>Assembly</th>
<th>Qualification</th>
<th>Protoflight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Allow Flt + 5°C or 35 to 75°C or Allow Flt +20 &amp; -15°C</td>
<td>-35 to 75°C or Allow Flt +20 &amp; -15°C</td>
<td>Temp. within Allowable Flt &amp; not to exceed assembly PF.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cycles: 1-10 depending on mission cycles. Electronics Dwell: 60 hr. hot / 8 hr. cold</td>
<td>Cycles: 1-10 depending on mission cycles. Electronics Dwell: 144 hr. hot / 24 hr. cold</td>
<td>Dwell time and Number of Thermal Cycles are Mission Dependent</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mechanisms Dwell: 24 hr. hot / 24 hr. cold</td>
<td>Mechanisms Dwell: 24 hr. hot / 24 hr. cold</td>
<td></td>
<td></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>
<td>Facility Limited</td>
</tr>
<tr>
<td>EMC</td>
<td>None</td>
<td>MEFL + 6 dB</td>
<td>MEFL + 6 dB</td>
<td>MEFL + 6 dB</td>
</tr>
<tr>
<td>RF Susceptibility</td>
<td>None (grounding/ isolation only)</td>
<td>Freq. Dependent Margin &gt; 60 dB</td>
<td>Freq. Dependent Margin &gt; 60 dB</td>
<td>Freq. Dependent Margin &gt; 60 dB</td>
</tr>
<tr>
<td>Emissions</td>
<td>None</td>
<td>MEFL - 6 dB</td>
<td>MEFL - 6 dB</td>
<td>MEFL - 6 dB</td>
</tr>
<tr>
<td>Radiated</td>
<td>(grounding/ isolation only)</td>
<td>Freq. Dependent</td>
<td>Freq. Dependent</td>
<td>Freq. Dependent</td>
</tr>
</tbody>
</table>

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### Thermal Margins Comparisons

Besides more conservative overall margin for JPL, there is another significant difference. The JPL approach requires the assessment of uncertainties in the definition of worst-case thermal scenarios.

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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

Backup
<table>
<thead>
<tr>
<th>TERMINOLOGY</th>
<th>BASIC</th>
<th>EUROPEAN</th>
<th>OTHER TERMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picaport</td>
<td>Part</td>
<td></td>
<td>component, element specific, item name</td>
</tr>
<tr>
<td>Assembly</td>
<td>Assembly (pt)</td>
<td></td>
<td>component, slice, tray, unit, element, trackbox</td>
</tr>
<tr>
<td>Subassembly</td>
<td>Assembly (pt)</td>
<td></td>
<td>component, slice, tray, unit, element, trackbox</td>
</tr>
<tr>
<td>Assembly</td>
<td>component, unit, section (attitude axis)</td>
<td></td>
<td>unit, element, trackbox instrument</td>
</tr>
<tr>
<td>Subsystem</td>
<td>Subsystem, instrument, module, structural assembly</td>
<td></td>
<td>unit, element, trackbox, instrument system</td>
</tr>
<tr>
<td>System</td>
<td>Payload, spacecraft, laboratory, detector, solar array</td>
<td>spacecraft</td>
<td>spacecraft, instrument, subsystem</td>
</tr>
</tbody>
</table>

Suggestions: all system, instrument, payload, issue 1) slice, tray, synonymous with subassembly, 2) make assembly brief up front in doc. list.

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