Overview of Power Quality and Integrated Testing at JSC

Francis Davies—Johnson Space Center
Overview

- Integrated testing: block diagram
- Partially integrated testing: block diagram
- Known Polarity/Phasing Related Errors in Space Systems
- Morpheus lander testing campaign
- EMU Integrated Tests
- ISS Power Lab (IPL)
- Energy Systems Test Area (ESTA)
- Examples of problems
System engineering divides a system into subsystems and characterizes the interfaces.

Interface tests often come in pairs that correspond and may have performance margins built in.
Partially integrated testing

**Testing at interfaces:**

Undocumented Interaction

Interface tests

**Slightly more integrated testing can catch undocumented interactions:**

Interface tests
Eight known US errors in recent history (since 1986) out of less than 1000 launches (Greater than 1 in 125).

<table>
<thead>
<tr>
<th>System</th>
<th>Date</th>
<th>Error</th>
<th>Impact</th>
<th>Integrated test?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chandra X-ray Telescope</td>
<td>1999</td>
<td>Sun sensor phasing error caught in post-integration testing.</td>
<td>Fixed prior to flight.</td>
<td></td>
</tr>
<tr>
<td>Apollo LM</td>
<td>~ 1968</td>
<td>ICD and simulator models incorrect, driving descent engine gimbals in wrong direction.</td>
<td>Fixed prior to flight.</td>
<td>yes</td>
</tr>
<tr>
<td>Delta Clipper (DCX)</td>
<td>1993</td>
<td>Sign error in control loop caught during integrated closed-loop pendulum test.</td>
<td>Fixed prior to flight.</td>
<td>yes</td>
</tr>
<tr>
<td>Galileo Spacecraft Probe</td>
<td>1995</td>
<td>High G and low G g-switches cross-wired.</td>
<td>Parachute deployed at wrong altitude but mission still successful.</td>
<td></td>
</tr>
<tr>
<td>TIMED</td>
<td>2001</td>
<td>Sun sensors were mounted 90 degrees off. Polarity on magneto-torquers reversed.</td>
<td>Fixed in software after launch</td>
<td></td>
</tr>
<tr>
<td>TERRIERS</td>
<td>1999</td>
<td>Sign flip in magneto-torquer command due to unknown cause.</td>
<td>Spacecraft lost.</td>
<td></td>
</tr>
<tr>
<td>Proton</td>
<td>2013</td>
<td>Yaw rate gyro was installed incorrectly.</td>
<td>Crashed near pad. laun</td>
<td></td>
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</tbody>
</table>

_Information From: NTRS document ID 20170012469_

“Lost in Translation: The Case for Integrated Testing” by Aaron Young and Steven Novack
Morpheus lander testing campaign

An example of complete integrated testing at JSC:

Pictures from: “Morpheus Lander Testing Campaign”
By Jeremy J. Hart and Jennifer D. Mitchell
Presented at the 2012 IEEE Aerospace Conference
The EMU (spacesuit) can be thought of as a complete system and JSC does a lot of integrated system level testing:

**ETA/Airlock Human-Rated Chamber**

**20-foot Human-Rated Chamber**

Pictures from: NASA website
Pictures from: email from IPL manager
ISS Power Lab

<table>
<thead>
<tr>
<th>Power Generation Tests</th>
<th>Fault Tests</th>
<th>ISS Payload Tests</th>
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<tr>
<td>Power Quality Tests</td>
<td>Control Tests</td>
<td>FDIR Tests</td>
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<tr>
<td>Battery Control Tests</td>
<td>PPL Checkout</td>
<td>FOD Procedure Checkout</td>
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<tr>
<td>Software Modification Checkout</td>
<td>ITR to IPL HW Test</td>
<td>EPS ORU Firmware Update</td>
</tr>
<tr>
<td>On-orbit Anomaly Resolution</td>
<td>Data Bus Analysis</td>
<td>Payload Functional checkout</td>
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<tr>
<td>Activities</td>
<td></td>
<td></td>
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<tr>
<td>Hardware and Software</td>
<td></td>
<td>Fit Check Demonstration</td>
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<tr>
<td>Integration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardware Modification Checkout</td>
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</tbody>
</table>

IPL provides the ISS Program with a resource to support the following tasks:
IPL hardware contains 2 PV IEA channels of EPS ORUs (DCSU, BCDU, PFCS, DDCU, RPCM, ECU, SSU), 4 S0 MBSUs, 4 S0 DDCUEs, 6 internal DDCUs, 2 PEU (PCU electronics), RPCMs, P4 NiH² Batteries, SSLA, Li-Ion Batteries, ARCU, CHT , DDCUR, RACU, and CCAA. The IPL hardware can change 1553 RT and bus to be placed in any configuration of the on orbit EPS system.
Energy Systems Test Area

B361

Facility power

Automate ISS testing

Power conditioning

Modular Batteries Fuel cell

FAB shop

Current ISS power testing

Power Breadboard

Customer hardware

Office

Buildup

Pictures from: email from ESTA manager
ISS POWER TESTING

ISS line matching
Impedance tester
Switching
RPC emulator
Test Hardware

Pictures from: email from ESTA manager
Problems found during testing

Problems with the power connection on hardware to be tested are so common that there is a specific step in the power quality test procedure to check for shorted or reversed inputs in the standard test procedure.

- Airlock air scavenger pump: Did not work with flight power supply.
- New Gen Food Warmer: control knobs labelled in wrong order
- Compressor unit: connector wiring changed