



Overview of Power Quality and Integrated Testing at JSC

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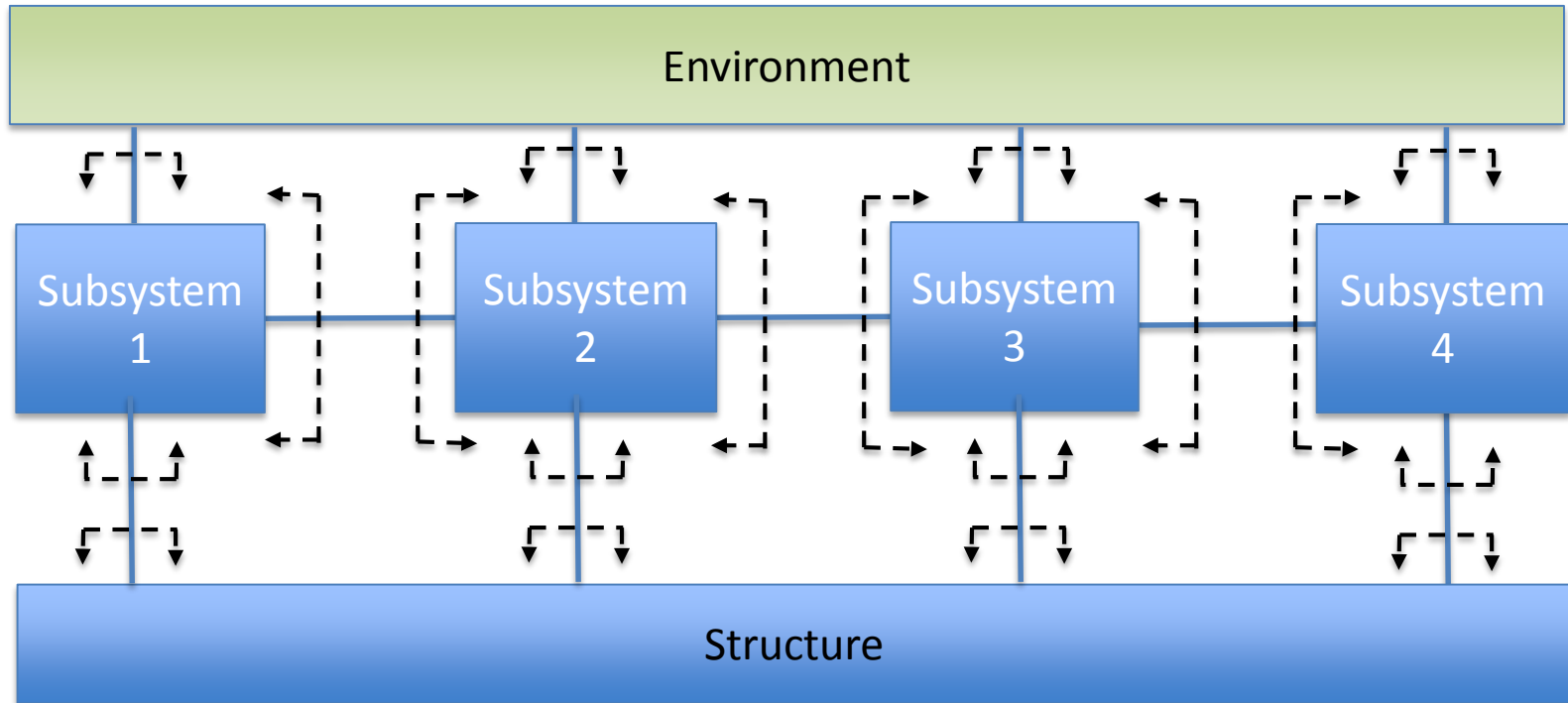


- Integrated testing: block diagram
- Partially integrated testing: block diagram
- Known Polarity/Phasing Related Errors in Space Systems
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- EMU Integrated Tests
- ISS Power Lab (IPL)
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- Examples of problems

Overview of integrated testing



System engineering divides a system into subsystems and characterizes the interfaces.

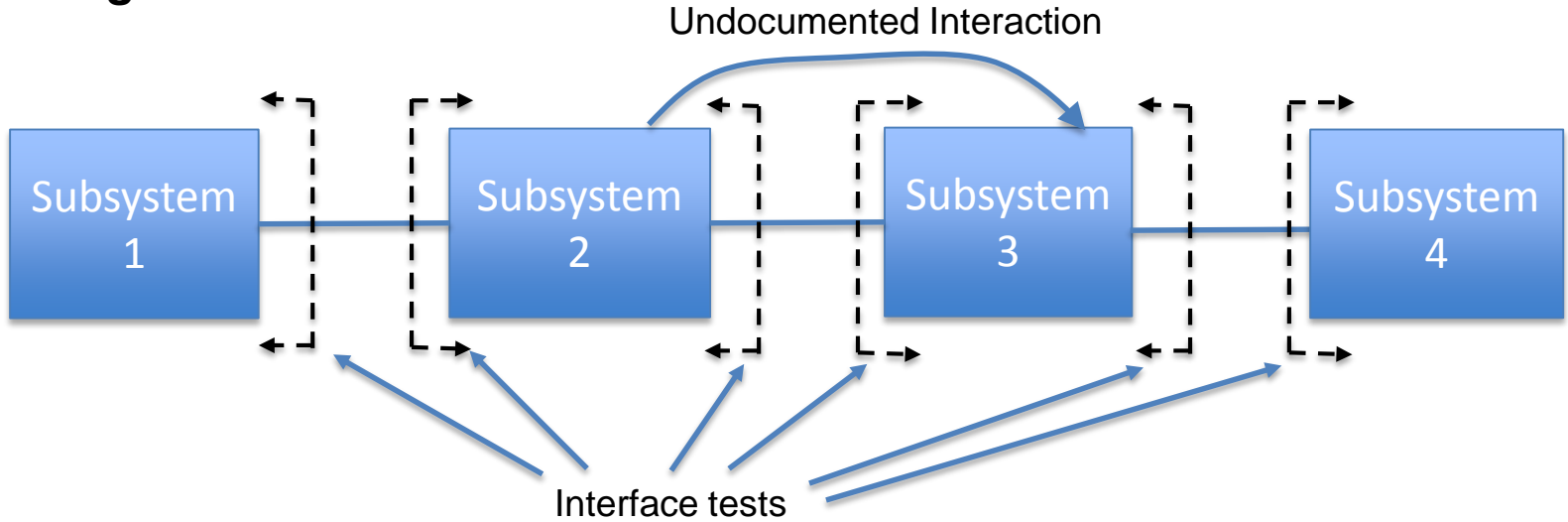


Interface tests often come in pairs that correspond and may have performance margins built in.

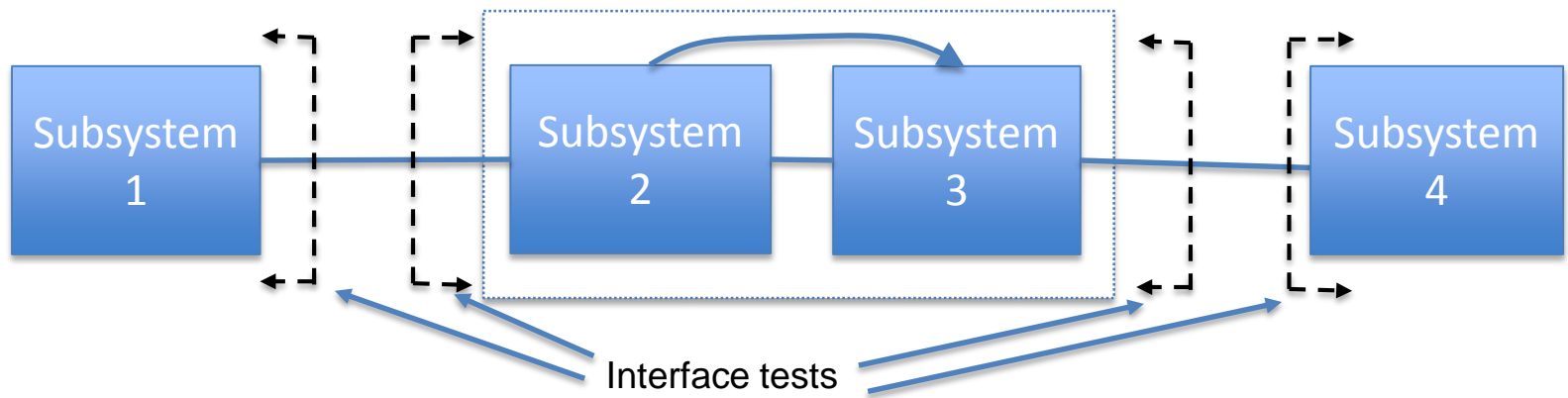
Partially integrated testing



Testing at interfaces:



Slightly more integrated testing can catch undocumented interactions:



Known Polarity/Phasing Related Errors in Space Systems



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

System	Date	Error	Impact	Integrated test?
Chandra X-ray Telescope	1999	Sun sensor phasing error caught in post-integration testing.	Fixed prior to flight.	
Apollo LM	~ 1968	ICD and simulator models incorrect, driving descent engine gimbals in wrong direction.	Fixed prior to flight.	yes
Delta Clipper (DCX)	1993	Sign error in control loop caught during integrated closed-loop pendulum test.	Fixed prior to flight.	yes
Galileo Spacecraft Probe	1995	High G and low G g-switches cross-wired.	Parachute deployed at wrong altitude but mission still successful.	
TOMS-EP	1996	Sun sensors cross-wired. Polarity on magneto-torquers reversed.	Fixed in software after launch	
TIMED	2001	Sun sensors were mounted 90 degrees off. Polarity on magneto-torquers reversed.	Fixed in software after launch	
Genesis	2004	Design error: G-switch installed backwards. Centrifuge test cancelled in favor of inspection.	Parachute failed to deploy. Spacecraft destroyed.	
TERRIERS	1999	Sign flip in magneto-torquer command due to unknown cause.	Spacecraft lost.	
Proton	2013	Yaw rate gyro was installed incorrectly.	Crashed nearch pad. laun	

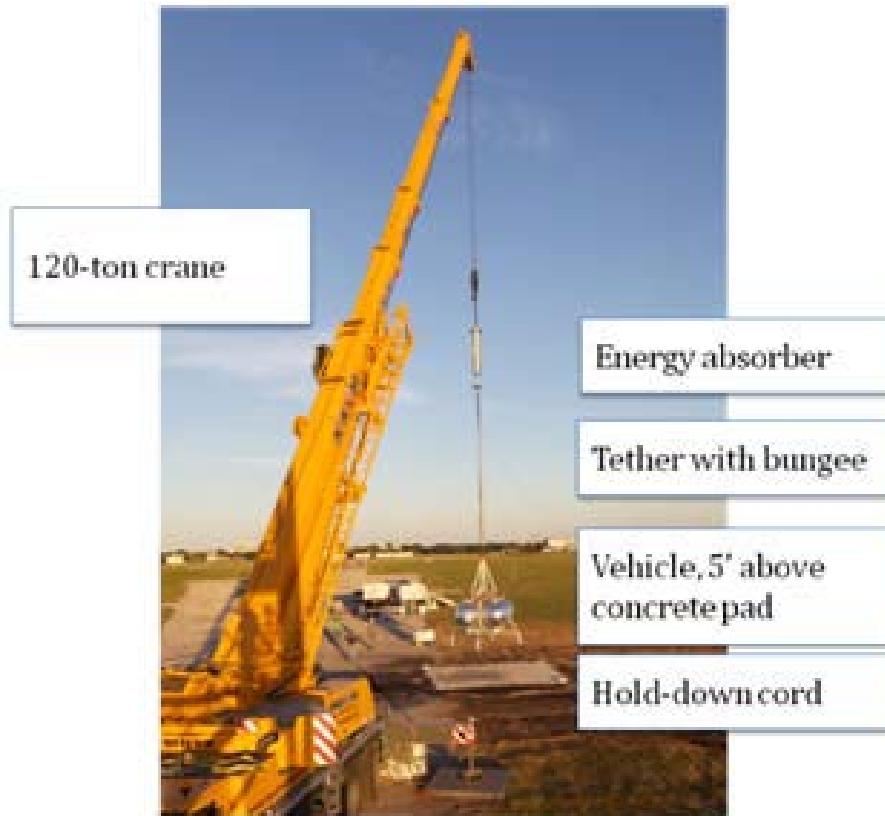
Information From: NTRS document ID 20170012469

“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

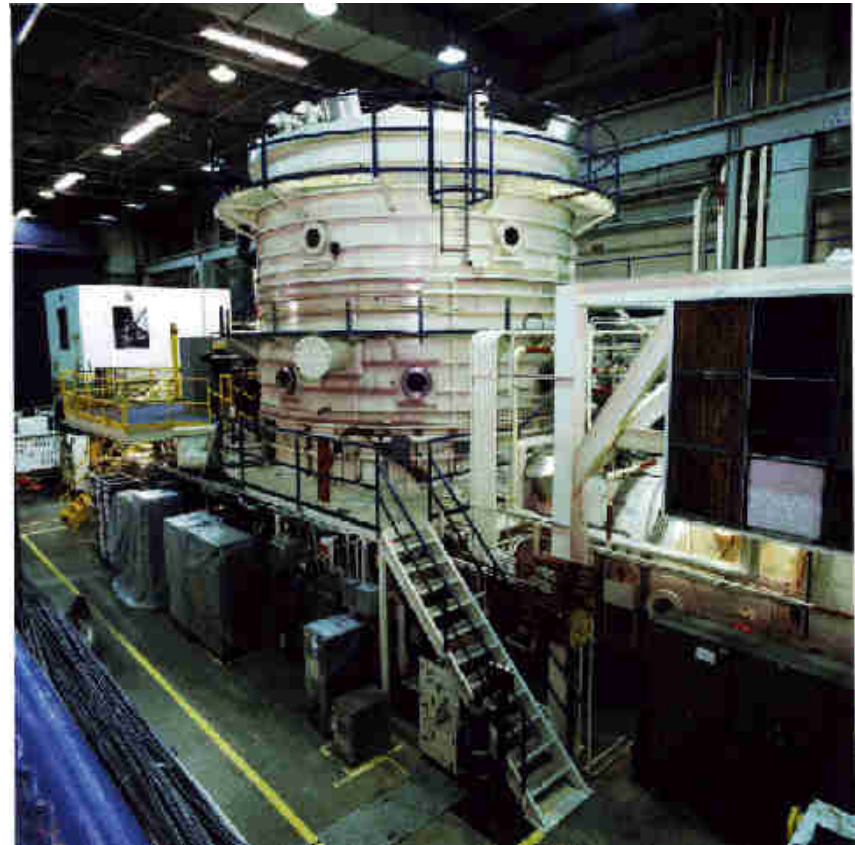
EMU Integrated Tests



The EMU (spacesuit) can be thought of as a complete system and JSC does a lot of integrated system level testing:



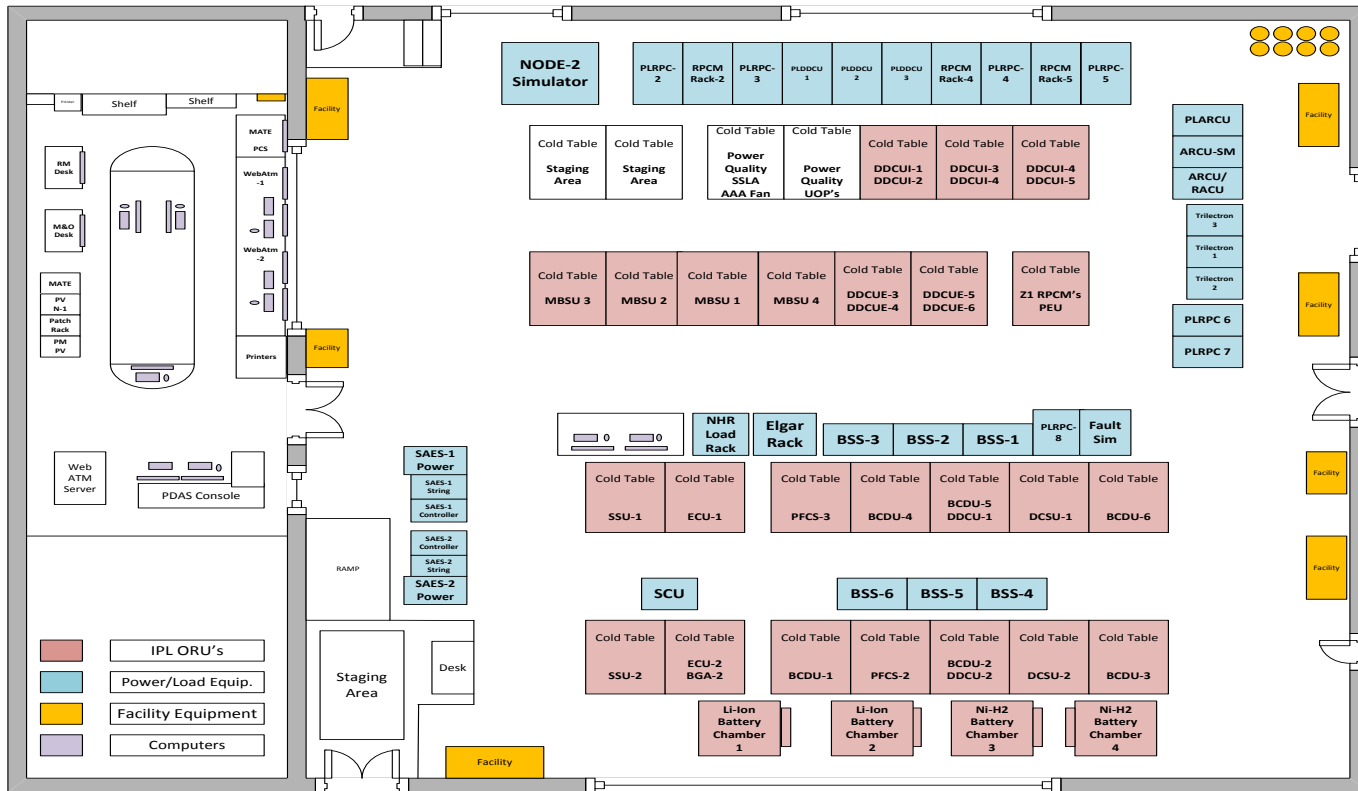
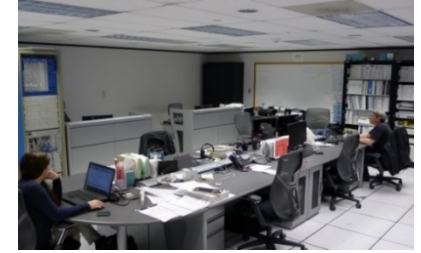
ETA/Airlock Human-Rated Chamber



20-foot Human-Rated Chamber

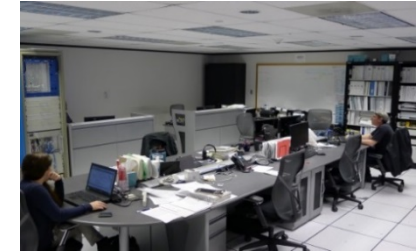
Pictures from: NASA website

ISS Power Lab



Pictures from: email from IPL manager

ISS Power Lab



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

IPL provides the ISS Program with a resource to support the following tasks:

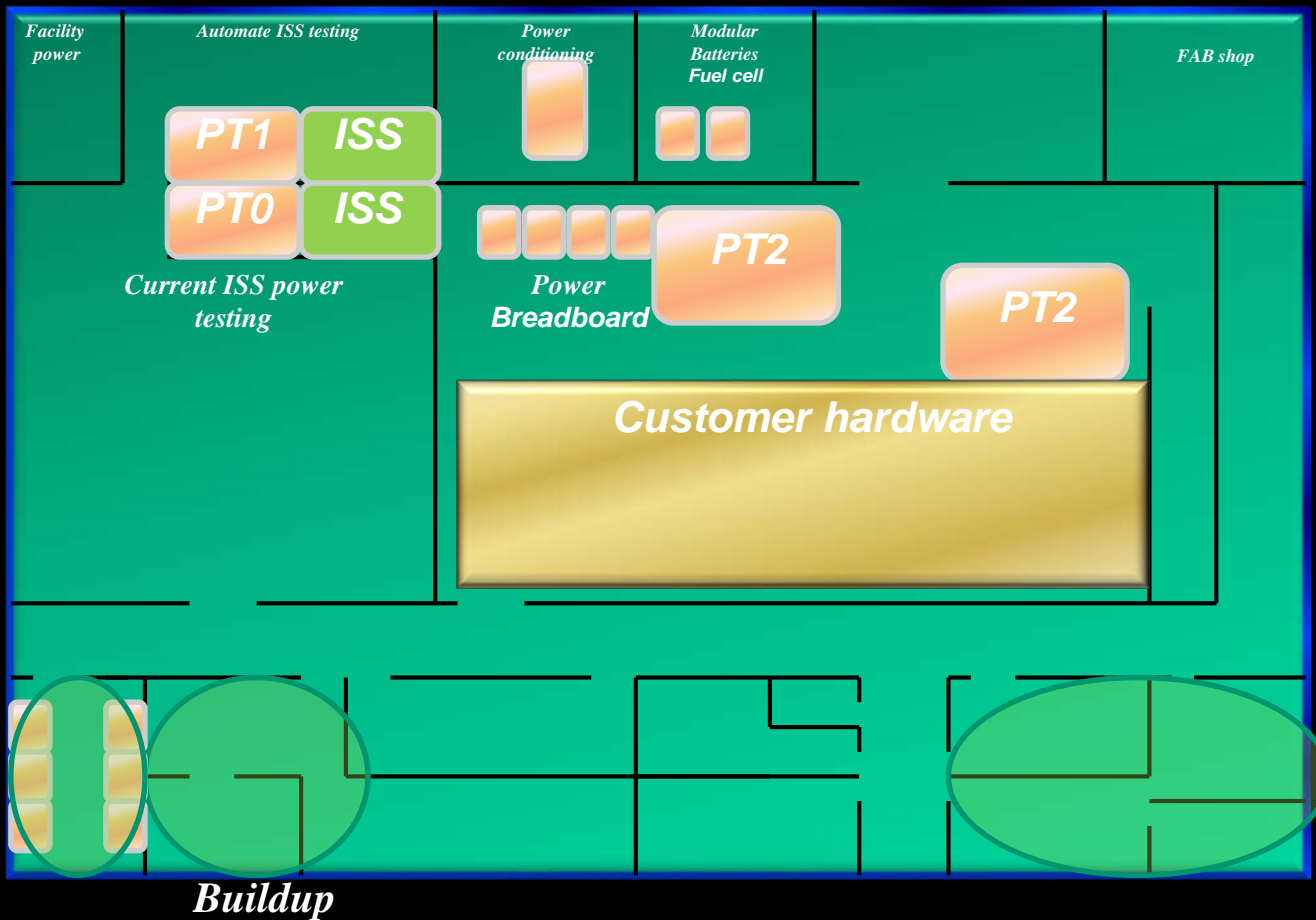
IPL hardware contains 2 PV IEA channels of EPS ORUs (DCSU, BCDU, PFCS, DDCU, RPCM, ECU, SSU), 4 S0 MBSUs, 4 S0 DDCUEs, 6 internal DDCUs, 2 PEU (PCU electronics), RPCMs, P4 NiH² Batteries, SSLA, Li-Ion Batteries, ARCU, CHT, DDCUR, RACU, and CCAA. The IPL hardware can change 1553 RT and bus to be placed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



Energy Systems Test Area



B361



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