PREFERRED RELIABILITY PRACTICES

BATTERY VERIFICATION THROUGH LONG-TERM SIMULATION

Practice:

Conduct highly instrumented real-time long term tests and accelerated testing of space flight batteries using automated systems that simulate prelaunch, launch, mission, and post mission environments to verify suitability for the mission, to confirm the acceptability of design configurations, to resolve mission anomalies, and to improve reliability.

Benefit:

Since the operational readiness and future performance of space flight batteries at any point in a mission are strongly dependent upon past power cycles and environments, thoroughly instrumented and analyzed ground testing of space flight batteries identical to flight configurations will ensure predictable performance and high reliability of flight batteries.

Programs That Certified Usage:

Hubble Space Telescope (HST), Advanced x-ray Astrophysics Facility (AXAF), External Tank (ET), Solid Rocket Booster (SRB), Inertial Upper Stage (IUS), and Combined Release and Radiation Effects Satellite (CRRES).

Center to Contact for More Information:

Marshall Space Flight Center (MSFC)

Implementation Method:

Real-time, long term mission, power cycle simulations of space flight batteries in ground facility test beds provide an excellent indication of expected performance in flight. Complete verification of a full real-time mission is not possible with long-term missions due to the test lead time. Instead of accelerating the test, the test engineers should “lead” the actual mission by a year or two (as long a lead-time as possible while still being able to use flight designs and configurations). This verification is in addition to qualification steps for the designs. Accelerated testing is not common for low earth orbit (LEO) missions but is used for non-LEO missions.

The cells are interconnected in the anticipated flight condition and are housed in a thermally controlled chamber which is purged with an inert gas. Preprogramed, computer controlled power supplies and load banks cycle the

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batteries through the same dormant, power drain, and charging cycles that they would encounter in the space operation. Shading of solar arrays during eclipse periods is simulated by absence of charging current, and charge cycles are simulated during exposure to the sun. Table 1 lists the principal purposes and features of long-term battery simulations.

Table 1. Principal Purposes and Features of Long-Term Battery Simulation

Purposes	Features
1. Evaluates suitability of proposed cell designs. 2. Determines compatibility and suitability of specific battery/power system configurations for specific long-term mission profiles. 3. Provides a test bed for simulation and resolution of in-flight anomalies.	1. Simulations include pre- and post-launch conditions as well as on-orbit conditions. 2. Either real-time or accelerated simulations are feasible. 3. Programmable load banks simulate flight power requirements. 4. Programmable power supplies simulate solar array output. 5. Testing is software-controlled and provides automated dialing to call in engineering assistance in the event of problems.

All cells are instrumented at various locations for current, voltage, temperature, and pressure. Ambient temperature in the chamber is constantly monitored. Voltage and current values are available in real time through digital readouts. Voltage, current, pressure, and temperature are recorded constantly on strip charts. Data are sampled by computer programs which compute and analyze ongoing performance. Table 2 shows the parameters usually recorded and/or computed for each battery cell from sampled data. Ground testing of batteries and their associated power systems has proven to be a valuable asset for the resolution of in-flight anomalies. Limits testing can be safely simulated on the ground to verify or explore variations in flight performance.

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Table 2. Recorded and Computed Data Parameters for Each Cell

1. Year	12. End of low rate charge pressure
2. Eclipse season number	13. End of discharge temperature
3. Orbit number	14. End of high rate charge temperature
4. Discharge time	15. End of low rate charge temperature
5. High rate charge time	16. Watt-hours out
6. Low rate charge time	17. Watt-hours in at end of high rate charge
7. End of discharge voltage	18. Watt-hours in over entire charge period
8. End of high rate charge voltage	19. Ampere-hours out
9. End of low rate charge voltage	20. Ampere-hours in over entire charge period
10. End of discharge cell pressure	21. Time in discharge or charge
11. End of high rate charge pressure	

Safety precautions are important in testing of all battery systems because leakage of electrolytes or effluents can be hazardous. Typical precautions and safeguards for nickel-hydrogen (Ni-H_2) batteries are shown in Table 3.

Table 3. Typical Precautions/Safeguards for Ni-H_2 Battery Testing

1. Prepare a comprehensive test plan before starting a long-life test.
2. A Safety Review Panel should review test plans and monitor the test program.
3. Batteries should be insulated to prevent convective heat transfer.
4. Tests should be conducted with the cells located in a thermally-controlled chamber with an inert gas environment.
5. All cells in a battery arrangement should be instrumented.
6. At least one engineer should be available to monitor every three tests in process.
7. Backup uninterruptible power supplies or generators should be provided for the test facility.
8. Automatic load removal should be activated if the power goes off.
9. Periodic test reports should be prepared with distribution to all concerned parties.

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An important action that will help to ensure a successful test effort is the preparation of a comprehensive test plan before the test begins. The test plan should describe the overall scope and approach to the test operation, and provide a detailed test sequence including the test set up parameters, data handling requirements, and test procedures. The test setup description should include the cell specifications and method of packaging into the battery configuration, the data acquisition and control procedures, and the thermal control system requirements. Test procedures should include cell characterization testing procedures (assuming that the cells have already passed through acceptance testing prior to receipt at the test site), launch scenario simulation procedures, mission simulation procedures, and mission capacity test and reconditioning procedures if required.

Technical Rationale:

MSFC has conducted multi-year testing of silver-zinc, nickel-cadmium, and nickel-hydrogen batteries since 1986. Some tests that were started in 1986 are still underway at this writing. Test durations are over eight years and counting. MSFC is conducting 8 to 10 tests simultaneously, with up to 400 channels of instrumentation some tests. To support the Hubble Space Telescope, diode bypass relays on two batteries were opened to simulate an in-flight anomaly. The HST ground tests indicated that strong performance should continue from the HST flight batteries despite the in-flight anomaly.

Impact of Nonpractice:

Failure to perform long term mission simulations will result in inadequate knowledge of long duration performance characteristics and could result in the retention of undesirable battery characteristics or failure modes that would result in mission failure.

Related Practices:

None

References:

1. Whitt, Thomas and Lorna Jackson: "Battery and Cell Testing at Marshall Space Flight Center," (a presentation), NASA/MSFC, EB12, Huntsville, AL, 1988.

2. Brewer, Jeffrey, John Pajak, and Lorna Jackson: "Test Plan for AXAF-I Ni-H_2 Battery Mission Simulation Testing," NASA/MSFC, EB71, Huntsville, AL, March 30, 1994.

3. Brewer, Jeffrey, and Thomas Whitt: "HST Ni-H_2 Flight Spare Battery Test," NASA/MSFC, EB12, Huntsville, AL, Huntsville, AL, October 6, 1989.

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4. Whitt, Thomas, and Charles Hall: "HST Ni-H_2 Six Battery Mission Simulation Test," NASA/MSFC, EB12, Huntsville, AL, November 2, 1989.

5. Whitt, Thomas, and Jeffrey Brewer: "Fifth Semi-Annual Report on HST Ni-H_2 Six Battery and Flight Spare Battery Test," NASA/MSFC, Huntsville, AL, August 8, 1993.