DS-2 MARS MICROPROBE BATTERY

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OUTLINE

• DS-2 MISSION OVERVIEW
• DS-2 BATTERY PERF. REQUIREMENTS
• BATTERY TECHNOLOGY CHALLENGES
• CHEMISTRY SELECTION
• CELL DESIGN OVERVIEW
• PROBLEMS ENCOUNTERED
• PERFORMANCE RESULTS
• CONCLUSIONS
NM DS-2 MISSION OVERVIEW

LAUNCH: JAN. 1999
IMPACT MARS: DEC. 1999

1998 NASA Aerospace Battery Workshop -93- General Session
DS2 MISSION OBJECTIVES

TECHNICAL OBJECTIVES

- Demonstrate key technologies which enable future network science missions (e.g., multiple landers, penetrators, or spacecraft)
- Demonstrate a passive atmospheric entry.
- Demonstrate highly integrated microelectronics which can withstand both low temperatures and high decelerations.
- Demonstrate in-situ, surface and subsurface science data acquisition

- Scientific Objectives

  - Determine if ice is present below the Martian surface
  - Measure the local atmospheric pressure
  - Characterize the thermal properties of the Martian subsurface soil
  - Estimate the vertical temperature gradient of the Martian soil
DS-2 AFTBODY

- Antenna
- Sun Sensor
- Transceiver
- Pressure Sensor
- Descent Accelerometer
- Batteries
- Mars Surface

Mars Microprobe in Landed Configuration (Aftbody)

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<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
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</thead>
<tbody>
<tr>
<td>Two 4 cell batteries</td>
<td>6-14 V</td>
</tr>
<tr>
<td>Battery Voltage:</td>
<td>550 mAh at -80°C</td>
</tr>
<tr>
<td>Battery Capacity:</td>
<td>2 Ah at 25°C</td>
</tr>
<tr>
<td>Shelf Life:</td>
<td>2.5 Years</td>
</tr>
<tr>
<td>Operating Temp.:</td>
<td>-60°C and below</td>
</tr>
<tr>
<td>Shock Impact:</td>
<td>80,000 g</td>
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</table>
Technology Challenges

- Ultra Low Temperature Operation (-80C)
- High Impact Shock Capability
- Minimal Voltage Delay at -60 C and below
- Three Year Shelf Life
Technical Approach

- Select Cell Chemistry
- Award Contract for Cell Fabrication
- Demonstrate Electrical Performance at -80°C
- Demonstrate Impact Resistance
- Demonstrate Life (Microcal)
- Demonstrate Safety
- Deliver Quality Cells to Project
DS 2 BATTERY
Li-SOCL₂ SYSTEM

Cell Voltage (V)

Current (A)

-100 C

0

1.0

1.5

2.0

2.5

3.0

3.5

4.0

-100 C

-80 C

-60 C

-40 C

-20 C

0 C

20 C
DS 2 BATTERY
Li-SOCl₂ CHEMISTRY DEVELOPMENT
Discharge curves of D-size Li-SOCl₂ Cell at -80°C at 120 ohm

Cell Voltage, V

Discharge Time, h

0.5M
1.5M
5 ohms

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Ds-2 Microprobe Battery

- Parallel Plate Configuration Perpendicular to Cyl. Axis
- LiGaCl$_4$/SOCl$_2$ Electrolyte
- Thin Electrodes
- Tefzel Spacer to Provide Stack Compression

INDUSTRIAL PARTNER: YARDNEY TECHNICAL PRODUCTS

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PROFILE TEST

Current (mA)

Voltage (V)

Temp (°C)

-15°C  -20°C  -30°C  -40°C  -80°C

0 Meets profile with conditioning
MICROCAL SUMMARY

Heat, Microwatts

Time, days

- Series1
- Power (Series1)

Max loss rate ≈ 100 μW = 26.9 μA = 0.2 Ah/yr
PROBLEMS ENCOUNTERED

- IMPACT SENSITIVITY
- CRACKING OF SEALS
- VOLTAGE DELAY
## IMPACT TESTING

### Problems Encountered

<table>
<thead>
<tr>
<th>TEST</th>
<th>DATE</th>
<th># Cells</th>
<th>CELL TYPE</th>
<th>PROBLEM</th>
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<tbody>
<tr>
<td>36</td>
<td>3/13/97</td>
<td>4</td>
<td>Old Design</td>
<td>Electrolyte Leak, GTM Cracks, Three Cells Functioned</td>
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<td>38</td>
<td>4/4/97</td>
<td>2</td>
<td>Old Design</td>
<td>Electrolyte Leak, GTM Cracks, Two Cells Functioned</td>
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<tr>
<td>42</td>
<td>5/29/97</td>
<td>8</td>
<td>Old Design</td>
<td>Electrolyte Leak, GTM Cracks, Seven Cells Functioned</td>
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<tr>
<td>50</td>
<td>8/28/97</td>
<td>8</td>
<td>New Design</td>
<td>One Cell Vented, One Cell Bulged, Seven Cells Functioned</td>
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<td>53</td>
<td>10/29/97</td>
<td>7</td>
<td>New Design</td>
<td>Electrochemical Technologies Group</td>
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</tbody>
</table>
SEAL PROBLEM

PROBLEMS

- RADIAL CRACKS (1-3) WERE OBSERVED IN THE GLASS TO METAL SEALS IN 34 OF 48 CELLS

- FOURTEEN CELLS SHOWED NO CRACKS ON INSPECTION

- CIRCUMFERENTIAL TOOL MARKS OBSERVED IN SOME SEALS CORRECTIVE ACTIONS

PRE WELD FILL TUBE

IMPROVED HEAT SINKING DURING CASE TO COVER WELD

CHANGE SEAL DIMENSIONS TO REDUCE STRESS

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VOLTAGE DELAY PROBLEM

PROBLEM

- Voltage delay in excess of 50 seconds was seen at temperatures lower than -45 C

CORRECTIVE SOLUTION

- Dry the Electrodes to Reduce Water Contamination
- Assemble the Cells within a Week of Electrode Manufacturing
- Ensure Electrolyte Purity (Iron, Water Content)
- Provide second depassivation pulse after landing
DS-2 Battery

Additional Tests Satisfied

Environmental
- Thermal cycling, -30 to +75°C.
- Quasi-static acceleration, 100g for 60 sec.
- Random vibration

Safety
- Discharge and Reversal at 114 mA, and at 25 and -80°C.
- Shorting across 0.020 Ohms.
DS-2 BATTERY ACCOMPLISHMENTS

- Demonstrated low temp (to -80°C) capability.
- Demonstrated capability to withstand shock.
- Demonstrated functionality for mission profile at low temp after shock.
- Demonstrated acceptably low self discharge for 2 year mission life.
- Delivered hardware and documentation.
DS-2 BATTERY CONCLUSIONS

- Can withstand shock (to 80,000 g).
- Can meet discharge profile post shock at Mars temps.
- Self discharge rate moderate but not excessive (0.2 Ah/year max).
- Can meet environmental requirements and tolerate electrical abuse.
DS-2 BATTERY
ACKNOWLEDGMENTS

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