



# MARS PATHFINDER BATTERY PERFORMANCE

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NASA BATTERY WORKSHOP  
HUNTSVILLE, ALABAMA  
NOVEMBER 18-20, 1997

ELECTROCHEMICAL TECHNOLOGIES GROUP

1997 NASA Aerospace Battery Workshop

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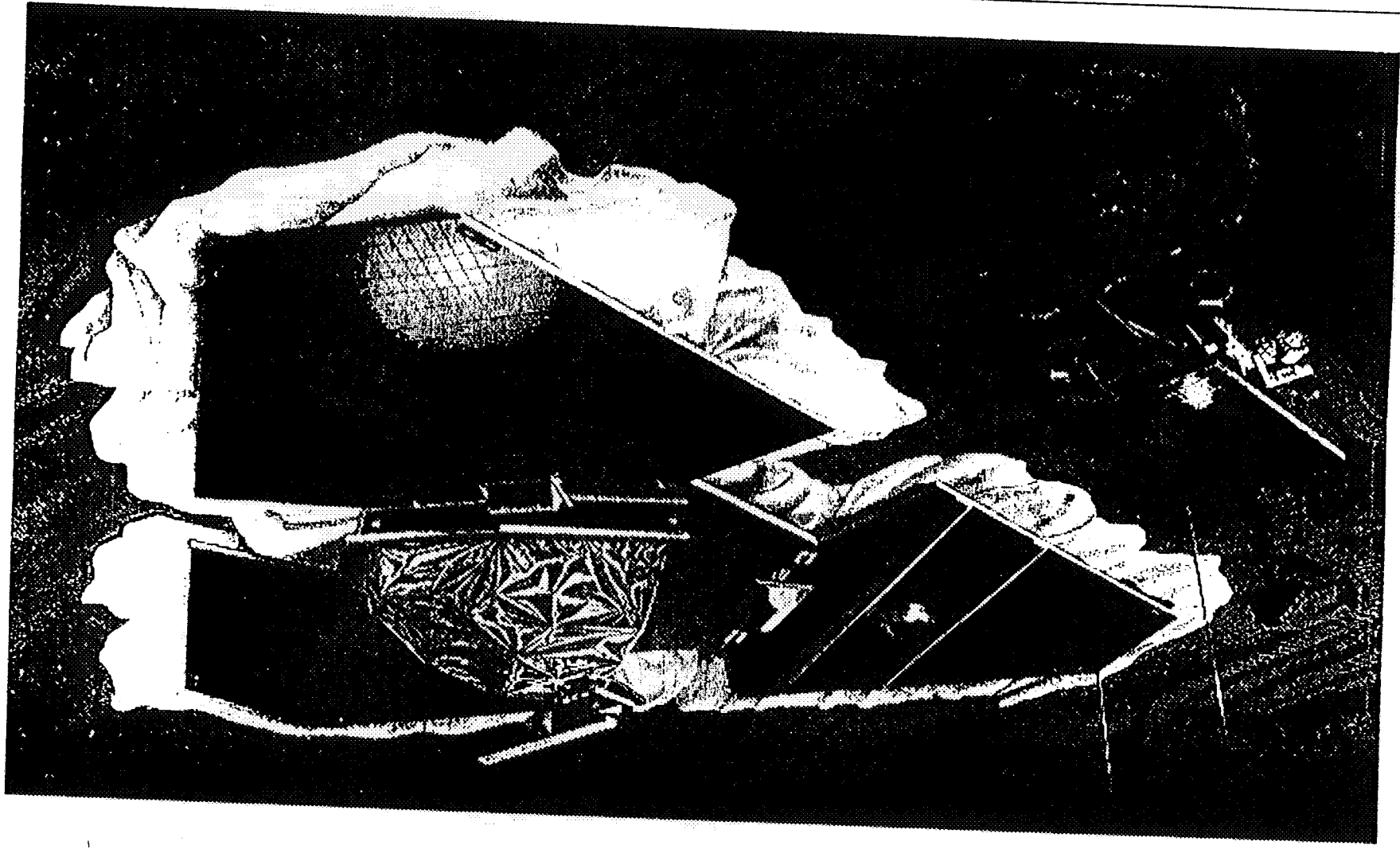
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# OUTLINE

- **MISSION REQUIREMENTS**
- **BATTERY DESIGN FEATURES**
- **BATTERY OPERATIONAL OVERVIEW**
- **BATTERY PERFORMANCE**
  - PRELAUNCH
  - CRUISE
  - EDL
  - MARS OPERATIONS
- **SUMMARY AND CONCLUSIONS**

# MARS PATHFINDER LANDER



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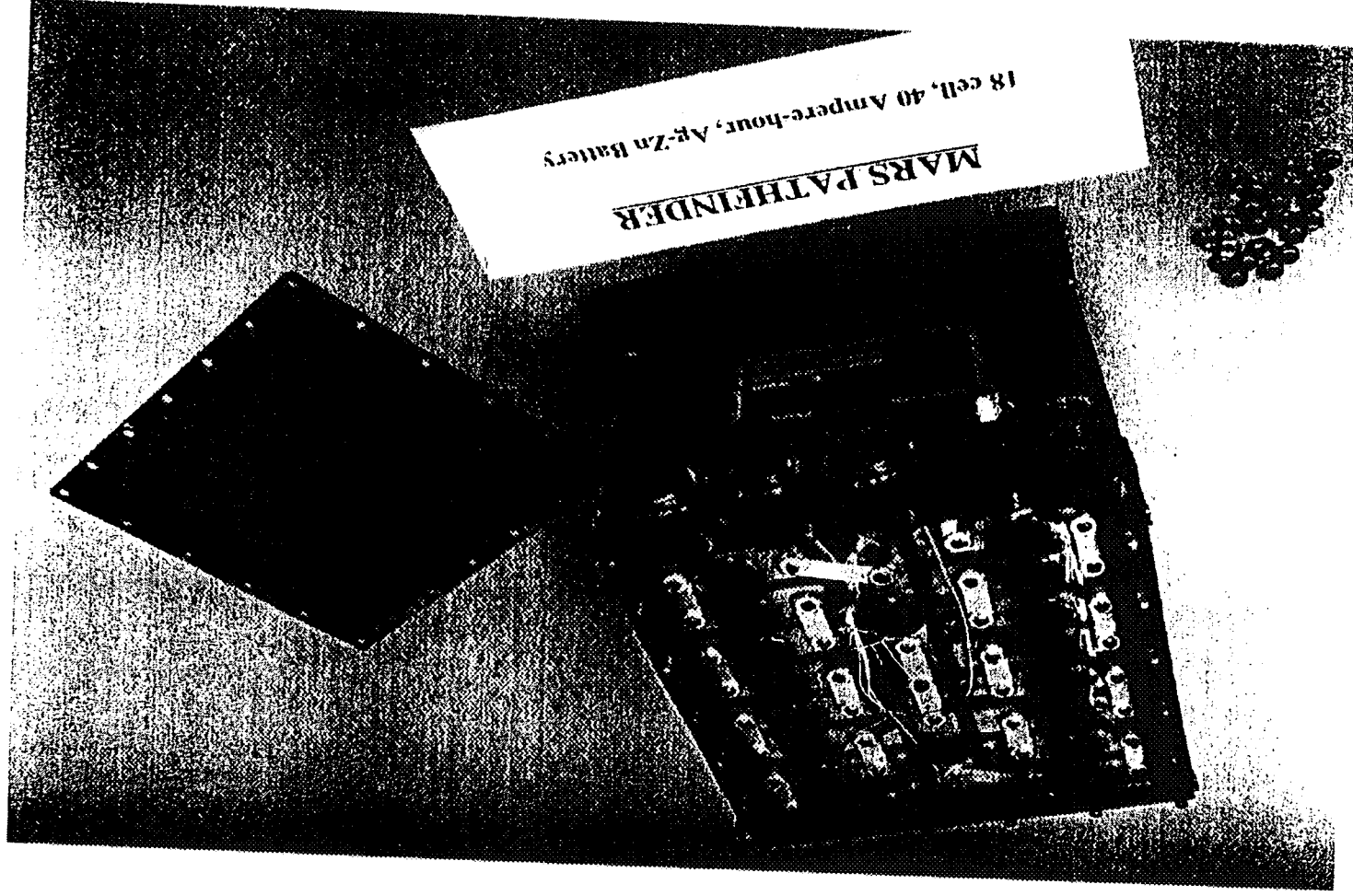
JPL



## MISSION REQUIREMENTS

- PRE LAUNCH 4 MONTH ACTIVE INVERTED STORAGE
- LAUNCH INVERTED BATTERY LAUNCH
- CRUISE 7 MONTH ACTIVE STORAGE
- EDL 40 AH, 1080 WH
- MARS OPR. CYCLES 30 CYCLES(1CYCLE/DAY, 8 HOUR CHARGE 16 HOUR DISCHARGE) 50% DOD
- WEIGHT 15 KG
- DIMENSIONS 9.8" x 7.4" x 7.4"

# MPF Ag-Zn BATTERY



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## MPF BATTERY SPECIFICATIONS

- **VOLTAGE** 27 V
- **CAPACITY** 40 Ah
- **RATE CAPABILITY** 1-5 A
- **PULSE CAPABILITY** 40 A FOR 40 MSEC
- **CYCLE LIFE** 40
- **WET LIFE** 14 MONTHS
- **WEIGHT** 15 KG
- **DIMENSIONS** 9.8" x 7.4" x 7.4"



## KEY CELL DESIGN FEATURES

- **Robust separator system - 5 layers of cellophane and 2 layers of polymer membrane.**  
To achieve long calendar and cycle life
- **Triple redundant case-to-cover seal including basic ultrasonic seal.**  
To prevent electrolyte leakage  
To improve safety
- **Large cell plate area - approximately 200 square inches.**  
Low temperature operation  
For enhanced pyro-firing
- **Unique leak-free cell vent valves.**  
For inverted battery operation  
allow gas venting under off-limit operation
- **Minimal free electrolyte**  
For inverted battery operation

## KEY BATTERY DESIGN & PROCESS FEATURES

- Titanium fabricated battery case with sealable cover and gasket.  
Light weight construction  
gas and electrolyte containment
- Battery vent valve and pressurization port.  
Redundant valve to protect cells from electrolyte loss
- Battery heater and two temperature sensors.  
Thermal management for charge control
- Over-pot of cells, surface conformal coating, connector back side potting and electrolyte absorption system.  
Prevent ionic conductive paths  
Improve safety
- Cell Matching and selection  
Extend cycle life

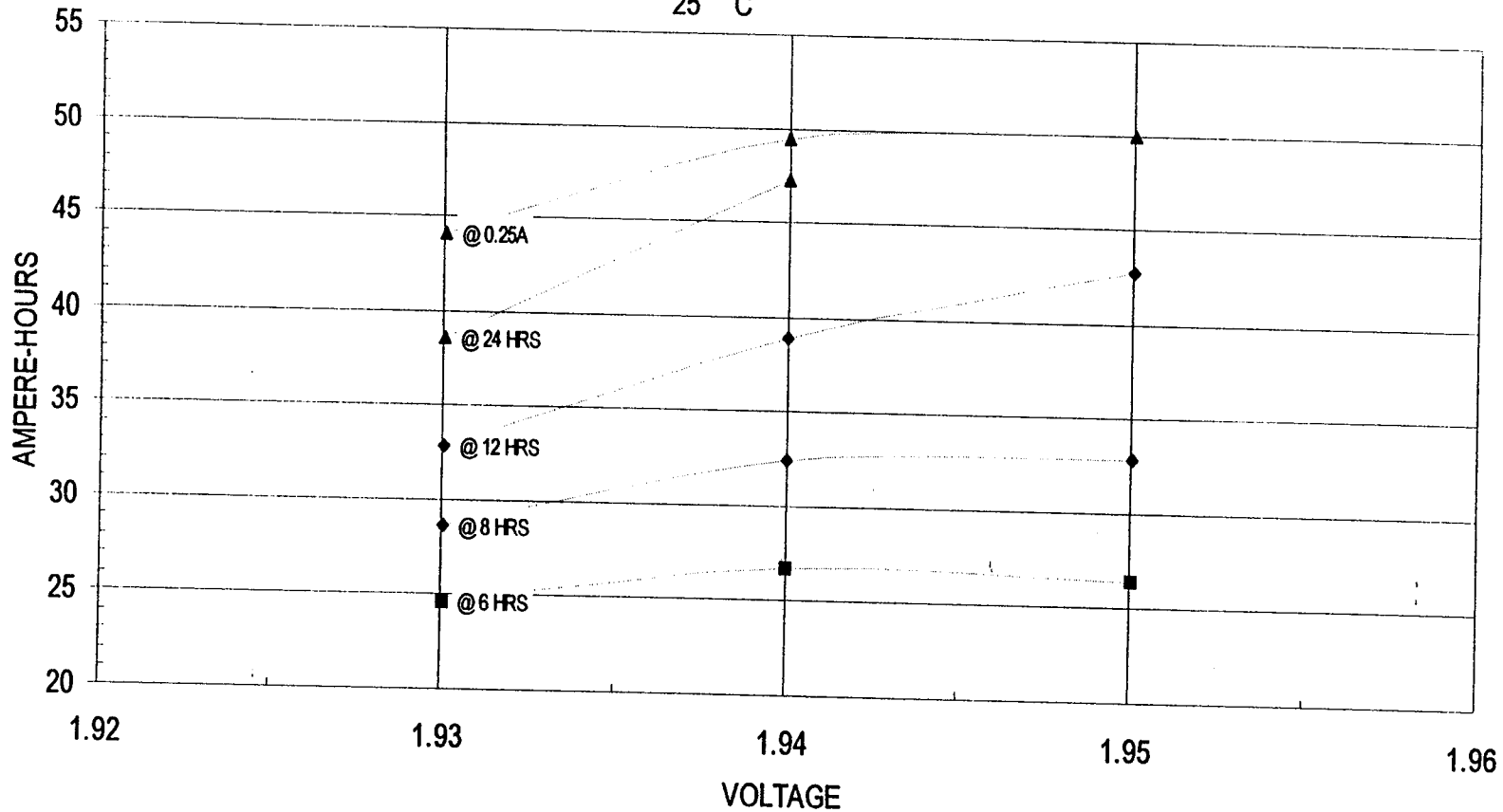


# KEY BATTERY OPERATING STRATEGIES

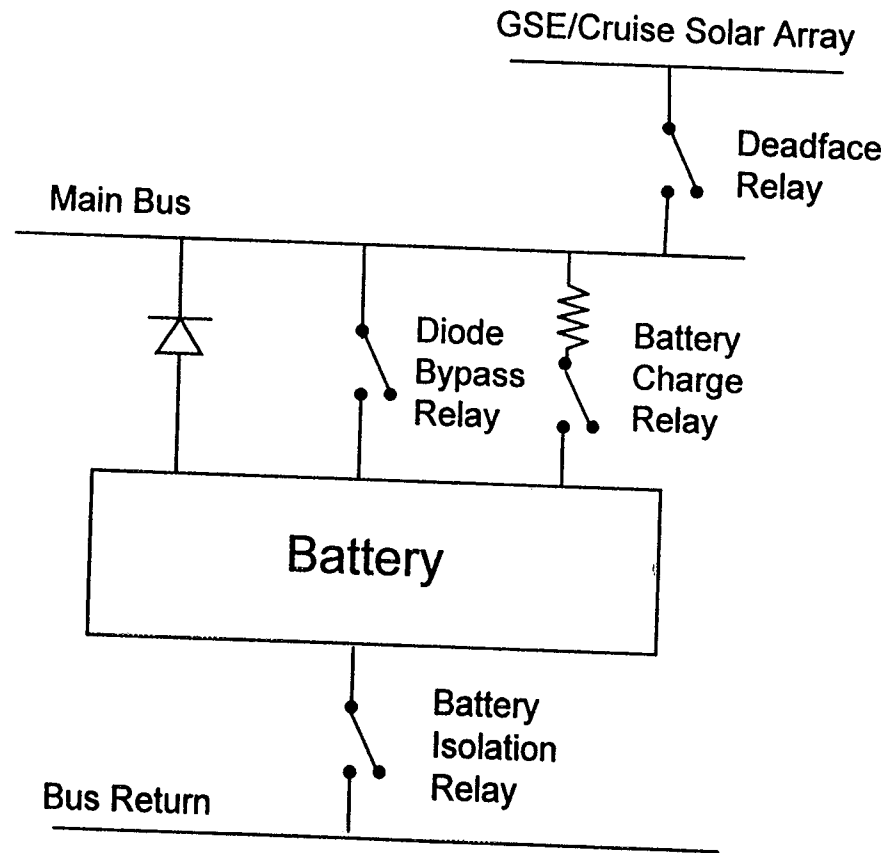
- Battery was mounted inverted and maintained at 12 C during pre-launch and launch Phases
- Battery was partially discharged to 80% SOC and on open circuit stand, at -5 to 0 degrees C, during 7 Month cruise period.
- Battery was charged at end of cruise through 1.2 Ohm resistor to 0.2 A cut-off and 1.95 V / cell Ave.
- Battery was heated to 15 to 20 degrees C prior to all charges.
- Battery was charged during Mars operations without resistor to a selective shunt limiter controlled maximum voltage. Six voltage settings were available with 1.95 V / cell Ave., the nominal full charge selection.
- Battery was taper charged to a constant shunt limiter voltage, 1.95 V / cell Ave.. well below the 2 V. limit employed in constant current charging with same full charge result.

# BATTERY CAPACITY VS CHARGE VOLTAGE

MARS PATHFINDER -- 16 BST Ag-Zn CELLS WITH 2+5 SEPARATOR SYSTEM  
CONSTANT VOLTAGE CHARGE CHARACTERISTIC FOR NEW CELLS WITH 4.5 AMPERE INRUSH AT  
25 °C

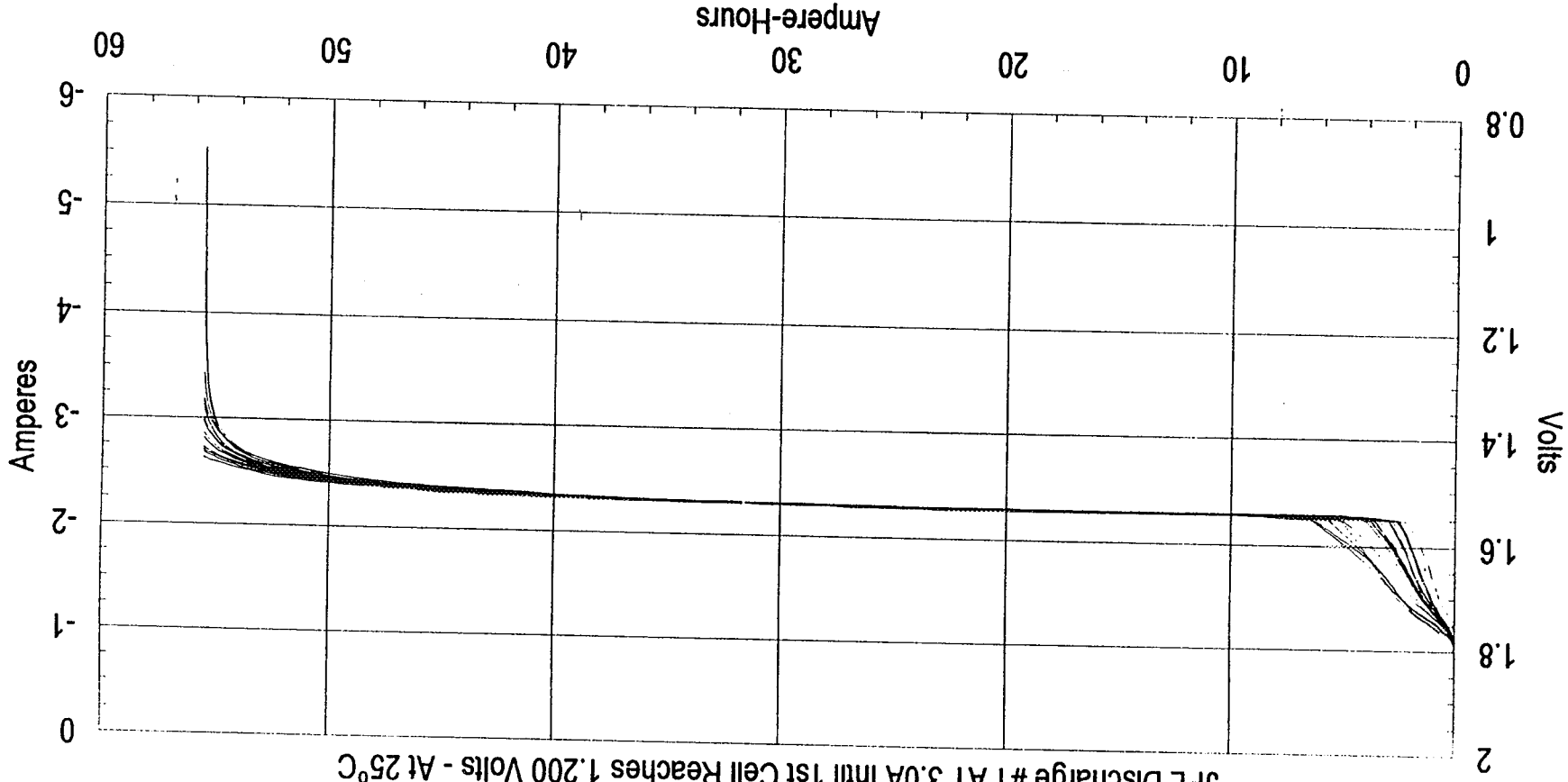


# MARS Pathfinder Power System Configuration Relays



# MPF BATTERY PRELAUNCH DISCHARGE

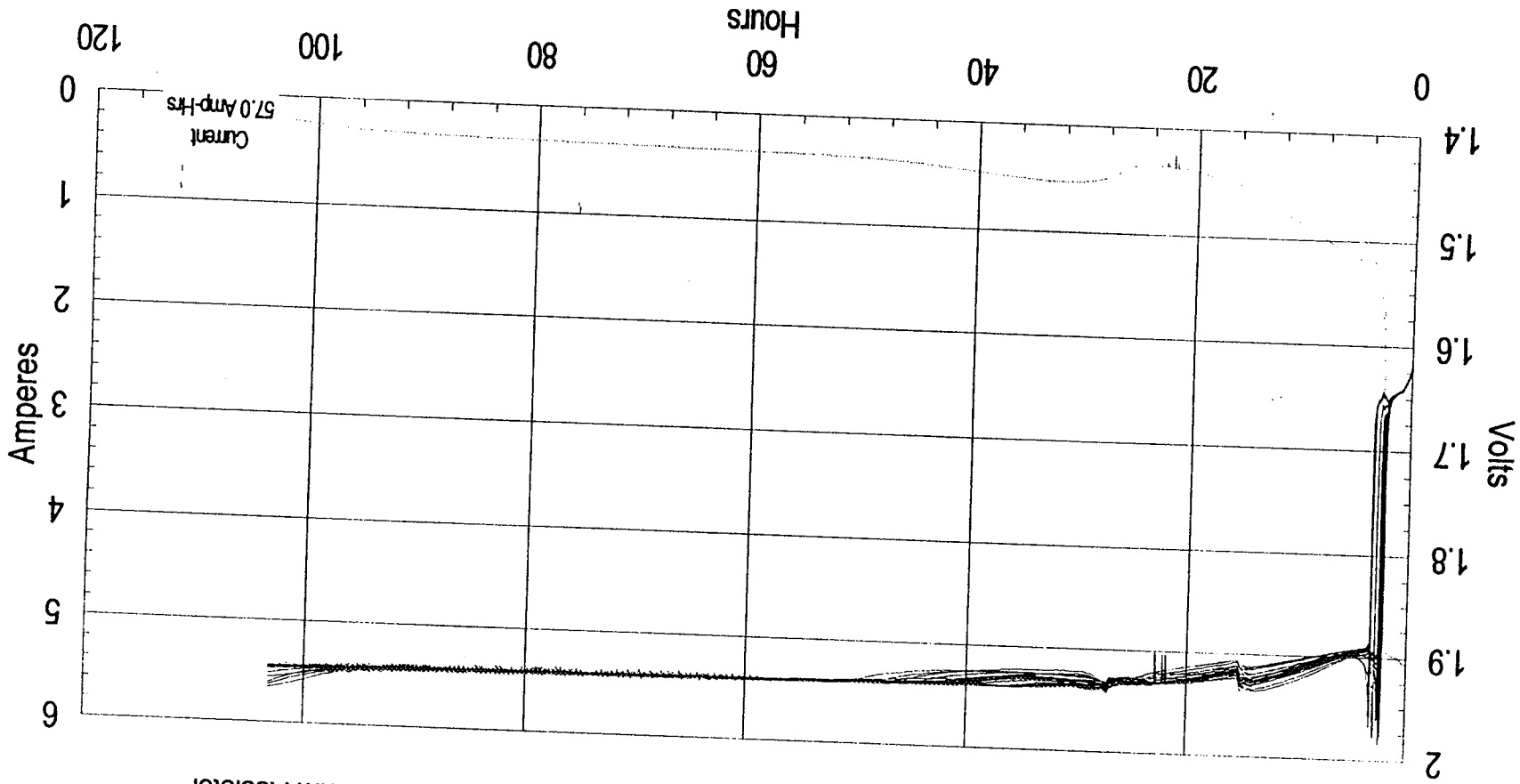
Mars Pathfinder -- BST 18 Cell 40 Ampere-Hour, Ag-Zn, Flight Battery  
JPL Discharge #1 AT 3.0A Infil 1st Cell Reaches 1.200 Volts - At 25°C



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# MPF BATTERY PRELAUNCH CHARGE

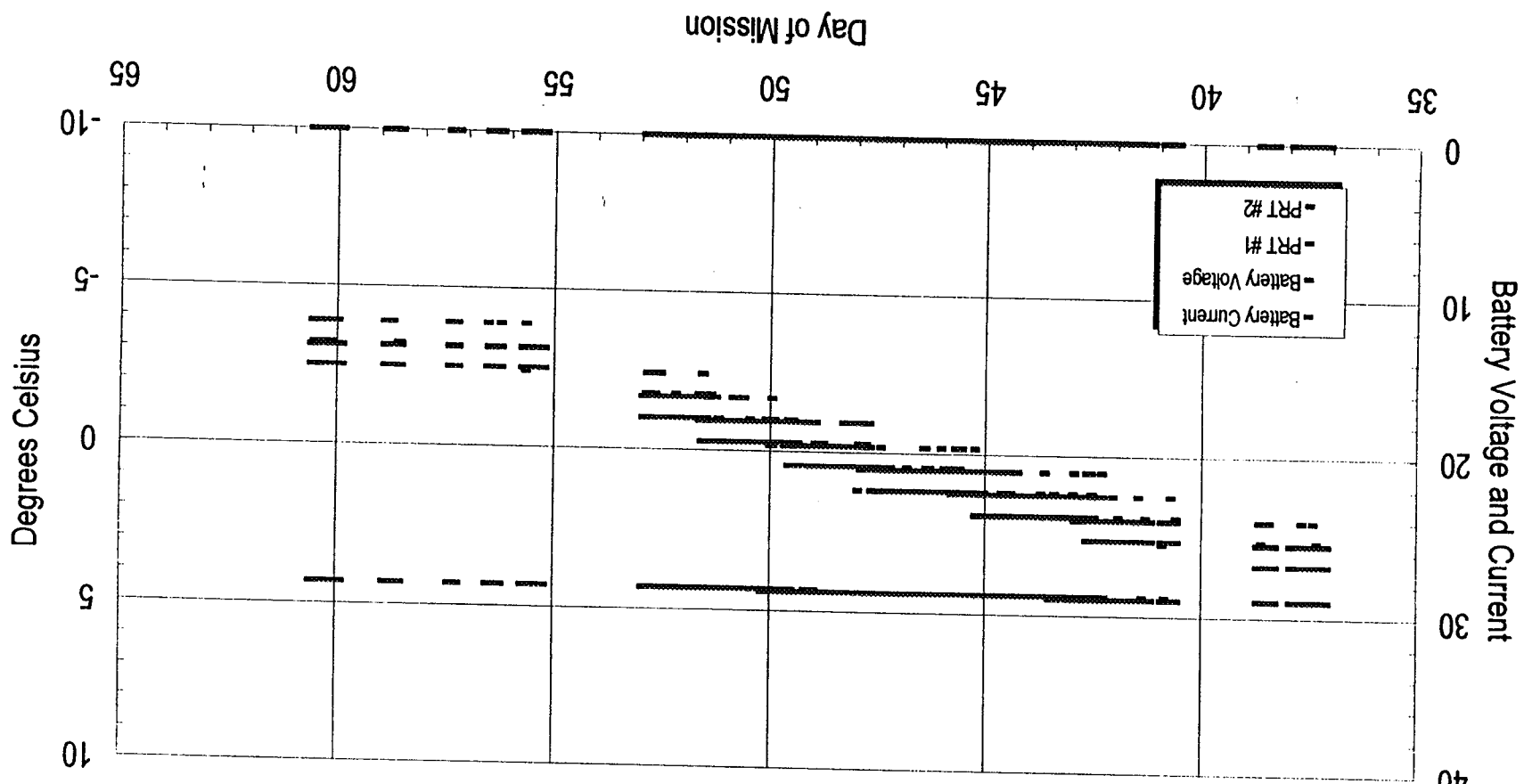
Mars Pathfinder -- BST 18 Cell, 40 Ampere-Hour, Ag-Zn, Flight Battery  
JPL Charge #2 AT 1.960 Volts Per Cell To A 0.2A Cut Off At 25°C - With 1.14 Ohm Resistor



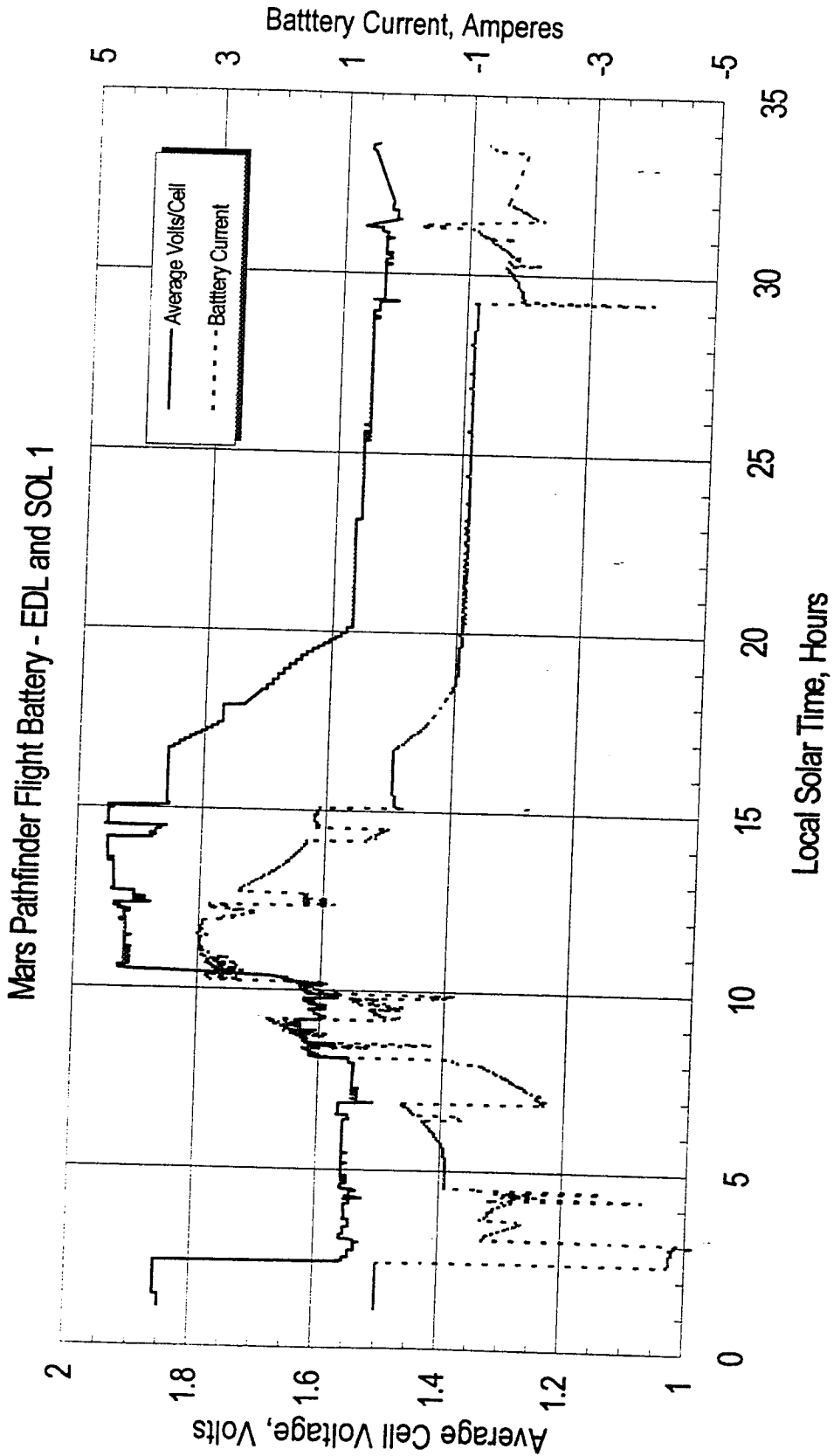
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# MPF BATTERY VOLTAGE AND TEMPERATURE DURING CRUISE

AgZn Battery Performance during Day 37 to 60 of Cruise

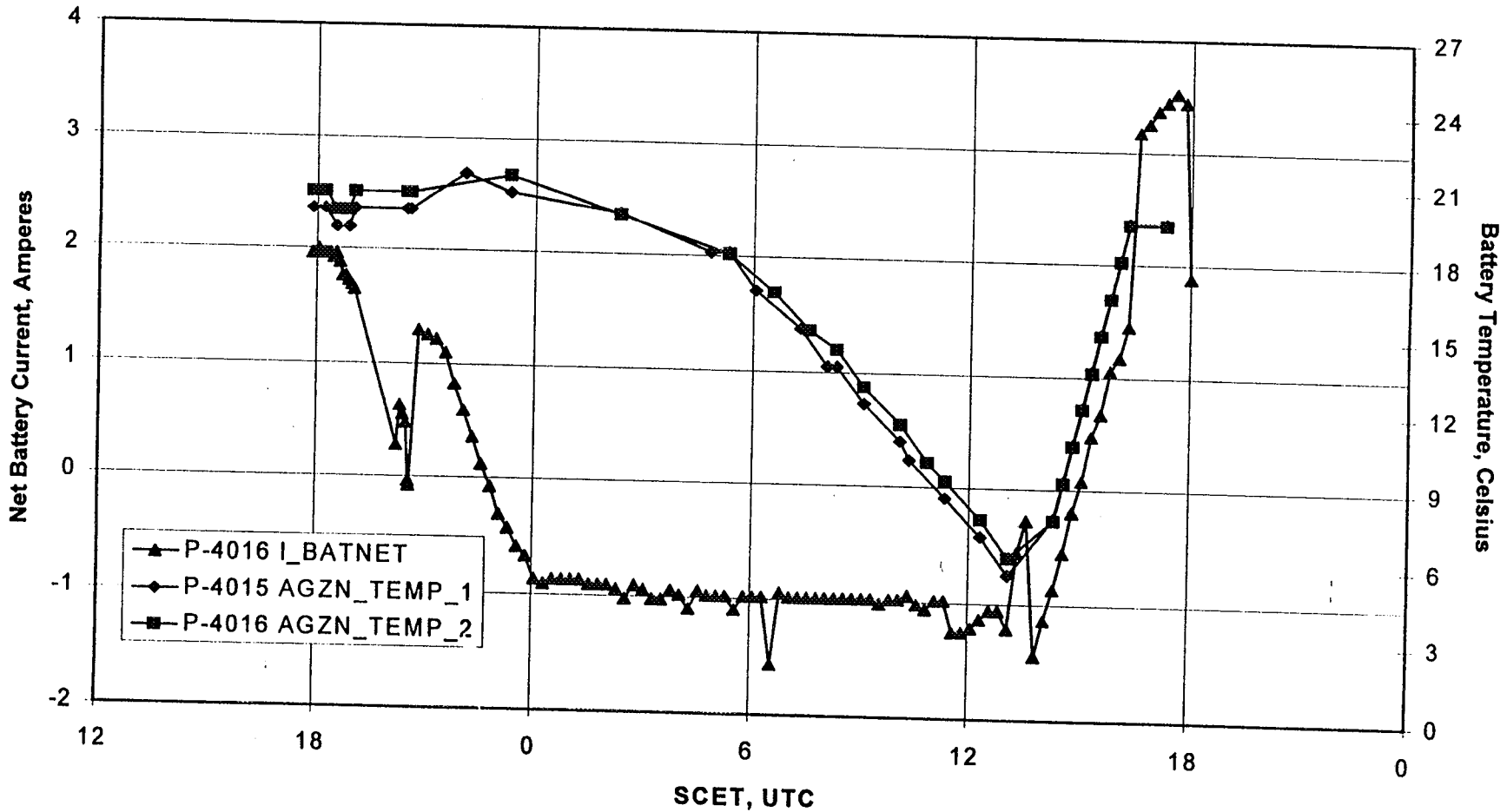


# MPF BATTERY PERFORMANCE-EDL/SOL1



# MPF BATTERY PERFORMANCE- SOL25

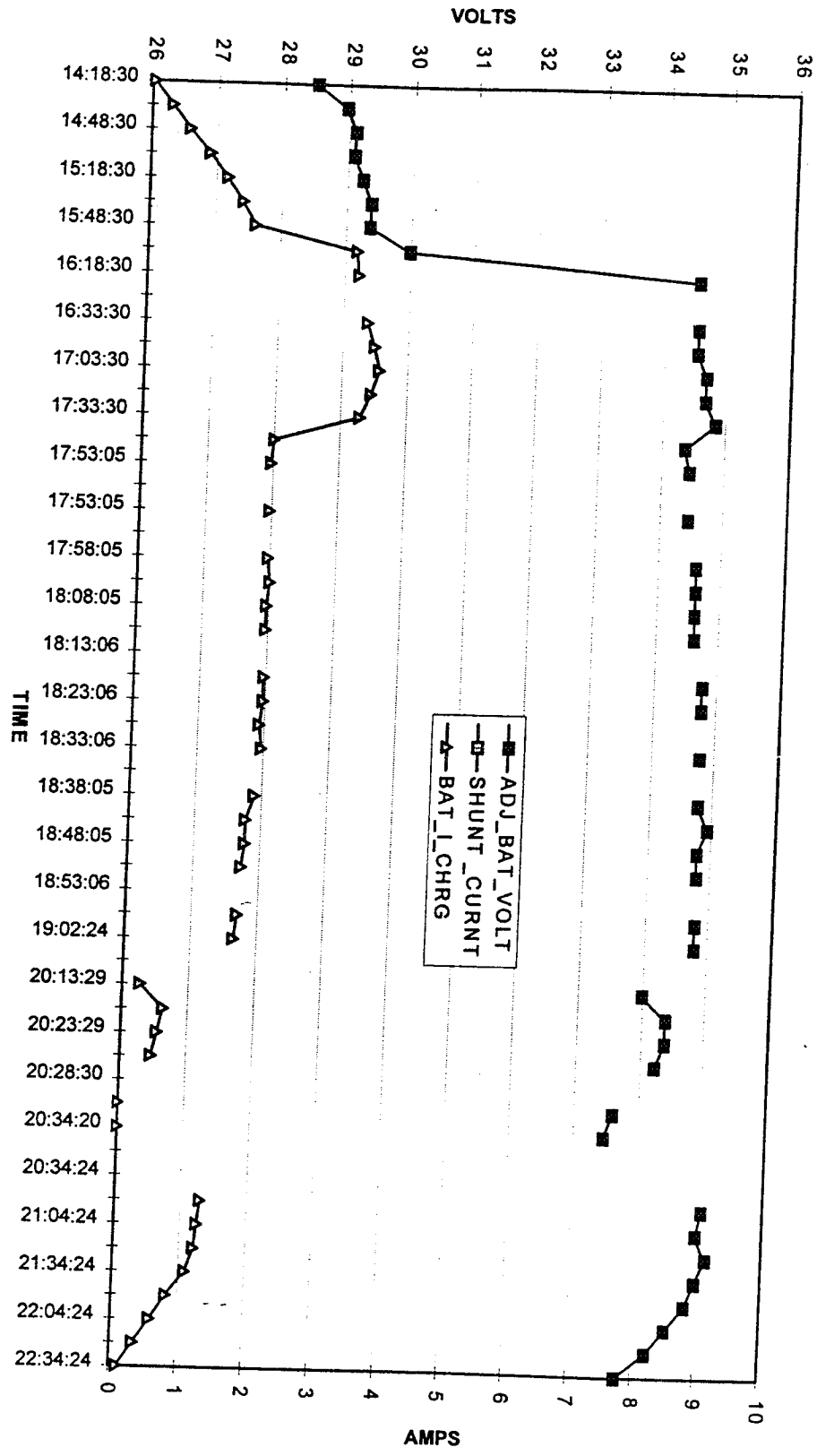
Flight Battery Sol 25 data





# MPF BATTERY PERFORMANCE SOL-25

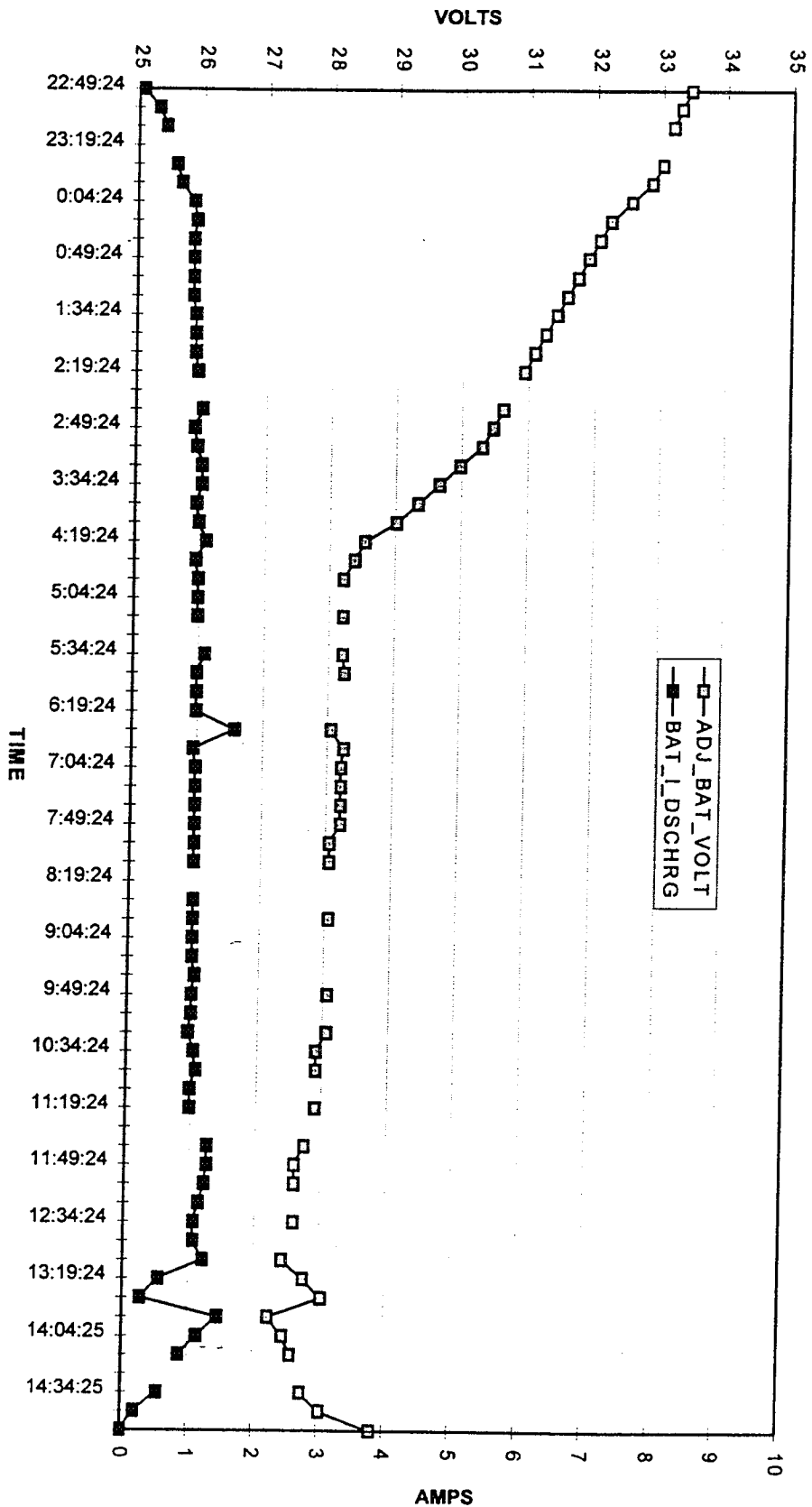
SOL #25 CHARGE





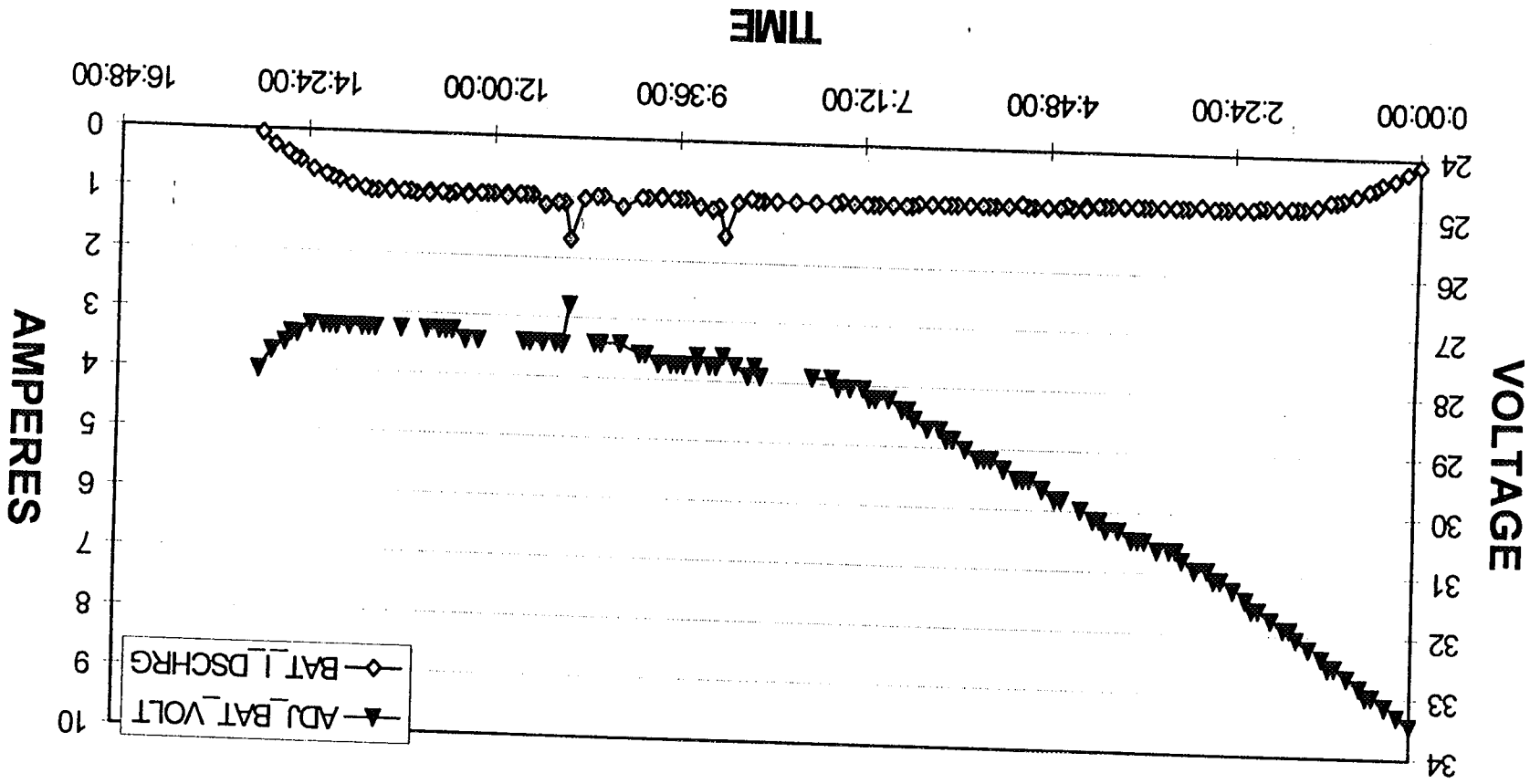
# MPF BATTERY PERFORMANCE-SOL 25

SOL #25 DISCHARGE



# MPF BATTERY PERFORMANCE-SOL 68

## SOL 68 DISCHARGE



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## SUMMARY AND CONCLUSIONS

- **The first use of a silver-zinc battery in a spacecraft application that called for extensive rechargeable operation after 12 months of active stand has proven to be very successful.**
- **BST has developed a silver-zinc battery with unique design features for the Mars Pathfinder mission.**
- **JPL has developed battery management strategies to meet the Mars Pathfinder mission requirements.**
  - Partial SOC at low temperature and open circuit stand was found to be the most effective method for insuring extensive cycle life following a long period of active storage
  - Silver-zinc battery charging at a reduced constant voltage was shown to provide full charge and a capability of supporting a large number of cycles.
  - Launch of an inverted silver-zinc battery was shown to be possible when a leak free cell vent valve is employed.
  - The use of a silver-zinc battery and shunt limiter in a direct energy transfer power system resulted in a very energy efficient design approach.



## ACKNOWLEDGMENT

The work described here was carried out at the Jet Propulsion Laboratory,  
California Institute of Technology, under contract with the  
National Aeronautics and Space Administration.

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