

**SODIUM SULFUR BATTERY CELL EXPERIMENT
(NaSBE)**

**Presented to the
1996 NASA Aerospace Battery Workshop
Huntsville, Alabama
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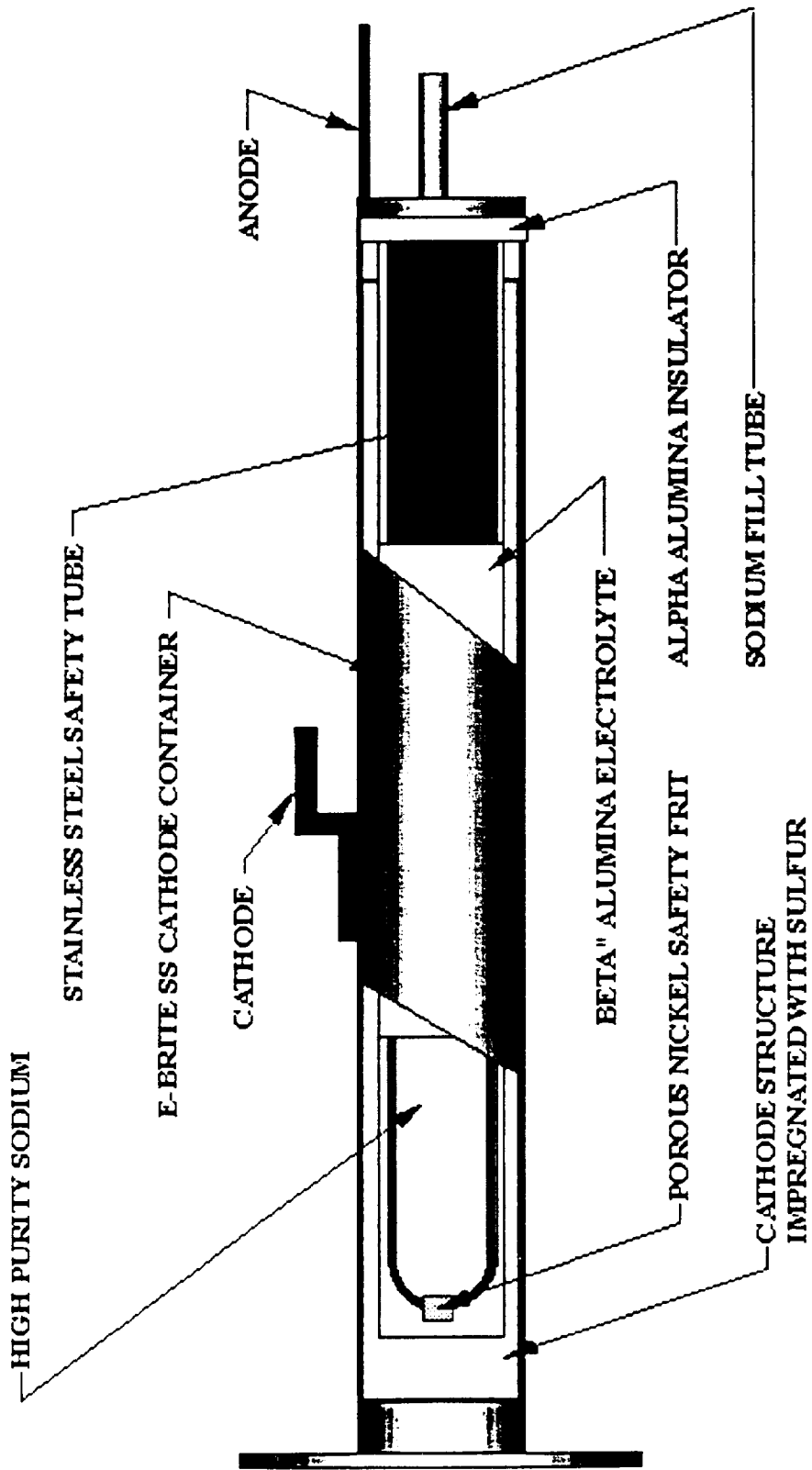


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INTRODUCTION - SODIUM SULFUR

- **1966 FORD MOTOR COMPANY PUBLISH PAPER DESCRIBING NEW TYPE OF SECONDARY BATTERY COMPRISED OF:**
 - **SOLID, SODIUM ION CONDUCTING ELECTROLYTE**
 - **LIQUID METAL ELECTRODE**
 - **REDOX ELECTRODE**
 - **OPERATING TEMPERATURE BETWEEN 300 AND 400° C**
 - **SPECIFIC ENERGY OF 150 Wh/Kg**
 - **NOMINAL VOLTAGE 2.0 V**

SODIUM SULFUR BATTERY CELL



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SODIUM SULFUR AEROSPACE HISTORY

- **LATE 1970'S USAF BEGINS DEVELOPMENT OF NaS FOR AEROSPACE**
 - 1979 AFWAL Tests Ford Aerospace Cells (6,300 Cycles)
 - 1983 AFWAL Funds Ford Aerospace Development of GEO Cells
 - 1986 AFWAL Funds EPI Development of LEO Cells , Hughes HEDRB Effort
 - 1992 NaS Efforts Transferred to USAF PL
- **1993 PL FUNDS EP 40 AH CELLS FOR GROUND TEST AND SAFETY TESTS**
 - Ground Test at NWSA, Crane (Simulated Leo,GEO Cycle Tests)
 - Safety Tests at Sandia National Labs
 - Vibration (Hot), Shock, Electrolyte Fracture
- **1994 USAF PL SIGNS MOA WITH NRL FOR FLIGHT EXPERIMENT**
 - Design, Build, Test One Brassboard & One Flight Experiment
 - Brassboard to Be Used As Ground Test Bed Delivered to USAF PL

FLIGHT EXPERIMENT PURPOSE

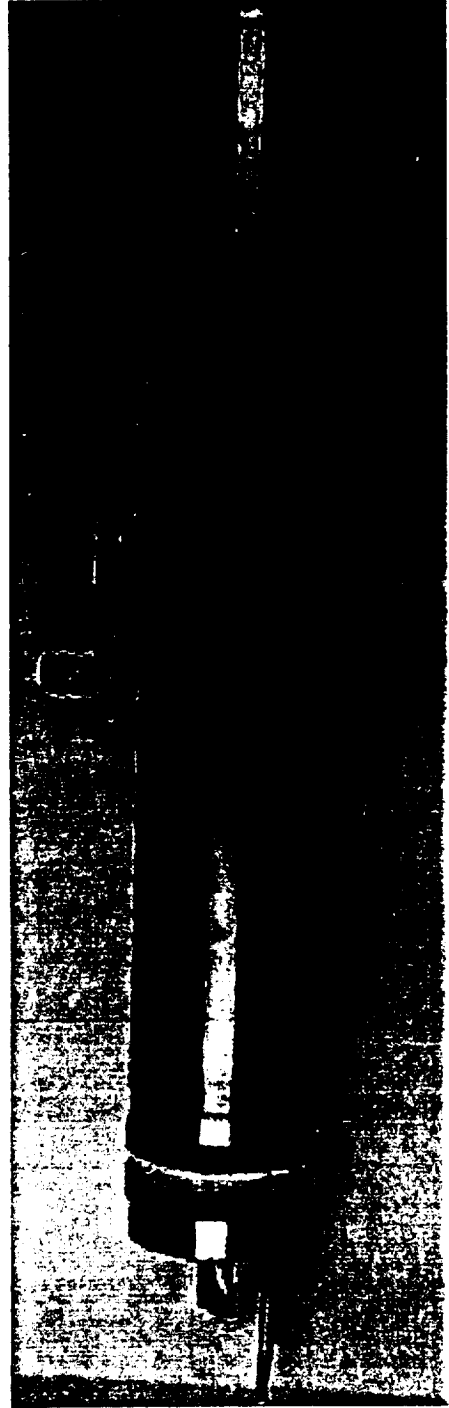
- **CHARACTERIZE NaS BATTERY CELL OPERATION IN ZERO-G**
 - Perform Post Flight DPA, Compare With Ground Test Cells
- **LEARN HOW TO WORK WITH A BATTERY SYSTEM THAT REQUIRES 350°C TEMPERATURES**
- **NAVIGATE EXPERIMENT THROUGH NASA SAFETY AND INTEGRATION PROCESS**

EXPERIMENT DESCRIPTION

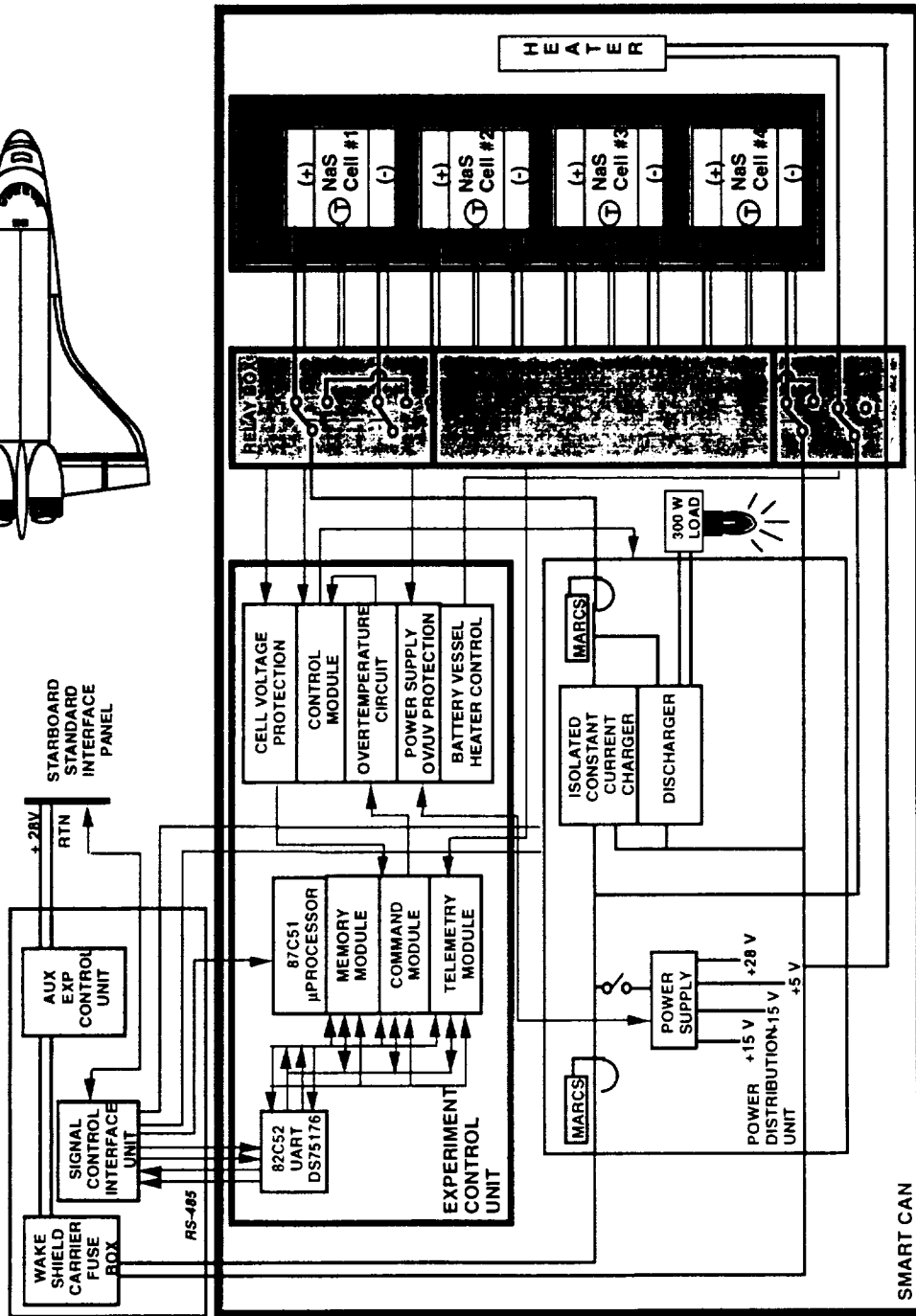
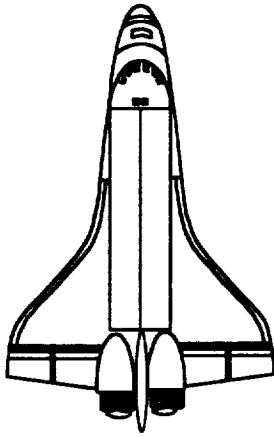
- LAUNCH 4 NaS BATTERY CELLS AT AMBIENT TEMP, CHARGED
- PHASE I - HEAT CELLS ON ORBIT TO 350°C
- PHASE II - (2) CAPACITY CYCLES
§ -20A Discharge to 1.65V, 4A Charge to 2.35V
- PHASE III - (2) SIMULATED GEO CYCLES
§ -20A Discharge for 1.2 Hr., 2A Charge for 12 Hr., 10.8 Hr. Open Circuit
- PHASE IV - (15) SIMULATED LEO CYCLES
§ -32A Discharge for 0.5 Hr., 16 a Charge for 1 Hour
- PHASE V - DISCHARGE CELLS TO 0%, 20%, 40%, 60% COOL TO AMBIENT
- FIT ENTIRE EXPERIMENT WITHIN NASA STANDARD GAS CAN
- LAUNCH WITH STS-80 ON WAKE SHIELD FACILITY 03

40 AH SODIUM SULFUR BATTERY CELL

- **CAPACITY** 40 AMPERE-HOURS
- **DIMENSIONS**
 - Length 0.240 m (9.44 inches)
 - Diameter 0.035 m (1.39 inches)
- **MASS** 0.580 KG (1.28 LBS)
- **SPECIFIC ENERGY** 138 WH/KG
- **MANUFACTURE** EAGLE PICHER INC., JOPLIN, MO
- **ELECTROLYTE** B" ALUMINA



EXPERIMENT BLOCK DIAGRAM



EXPERIMENT POWER ELECTRONICS

- **CHARGE BATTERY CELLS AT 2, 4 AND 16 AMP RATES**
- **DISCHARGE BATTERY CELLS AT -20 AND -32 AMP RATES**
 - Discharge 1 Cell to 60% Depth of Discharge
 - Use 3 Halogen Lamps As Discharge Loads
- **EXPERIMENT MUST FAIL SAFE**
 - Internal Power Supply Failure Shuts Down Entire Experiment
 - NaS Battery Cell Overtemperature Circuit
 - DISABLES BATTERY HEATER
 - DISABLES CHARGER AND DISCHARGER
 - NaS Battery Cell Over/Undervoltage Circuit
 - EACH CELL MONITORED INDIVIDUALLY
 - IF CELL VOLTAGE < 1.65 V OR > 2.5 V CELL IS REMOVED FROM CIRCUIT
 - All Power Lines Are Switched

EXPERIMENT TELEMETRY, COMMAND & CONTROL

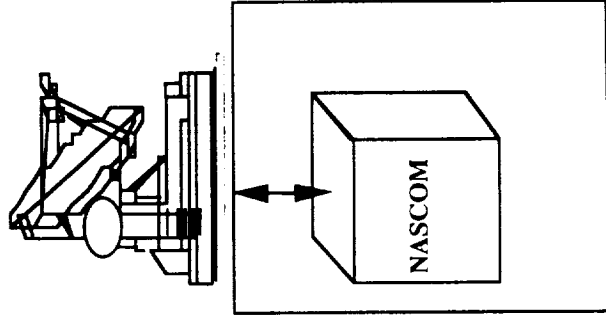
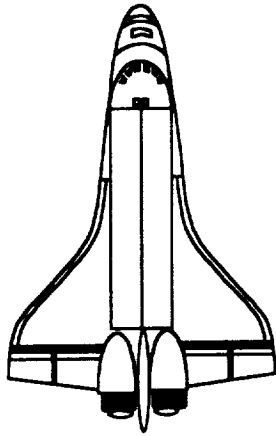
- **REQUIREMENTS**
 - Collects Telemetry From Experiment
 - Individual Cell Voltage, 4 Temperatures/Cell, Experiment Temperatures, Charge/Discharge Currents
 - Send Commands
 - Receive/X-Mit Commands & Telemetry From WSF CBC via RS-485
 - Store One Orbit Of Experiment TLM Data
- **IMPLEMENTATION**
 - Harris 82C52 UART & Processor For WSF Data Interface
 - Intel 87C51C μ Controller
 - 8051 Heritage
 - 32k EPROM
 - 256 Bytes RAM
 - 10 MHz Clock
 - 2 User Interrupts
 - 48k x 8 Total Memory For Experiment Data & Software
 - 16 Low Level Commands (200 μ S Pulse Width)
 - 16 High Level Commands (+28V, 40mS)
 - 32 Bi-Level TLM Points
 - 64 Analog TLM (48 Passive, 16 Active)

EXPERIMENT THERMAL DESIGN

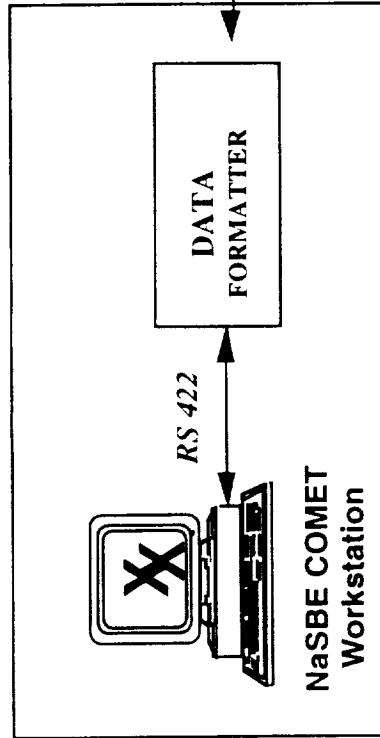
- **POWER GENERATED BY BATTERY CELLS IS DISSIPATED BY HALOGEN LIGHT BULBS OUTSIDE OF SMART CAN**
- **HOT VESSEL WRAPPED WITH A 4 PIECE 0.001M THICK MICA HEATER**
- **NaS CELL TEMPERATURES CONTROLLED WITHIN 350±20°C**
 - Monitor NaS Cell and Hot Vessel Temperatures
 - When NaS Cell Temp < 330°C , Thermostat Closes, Heater Power Applied
 - When Hot Vessel Temp < 330°C & NaS Cell Temp < 370°C, Thermostat Closes
 - When NaS Cell or Hot Vessel Temp > 370°C, Thermostat Opens
- **USE OF HIGH THERMAL RESISTANCE CERAMIC ISOLATORS TO OBTAIN DT BETWEEN HOT VESSEL & MID-DECK**

EXPERIMENT ON-ORBIT DATA TRANSFER

- GroundStation Uses OS Comet*
- RS422 From/To SHI & NASA JSC
- RS 485 From/To WSF & NaSBE



NASA JOHNSON SPACE FLIGHT CENTER

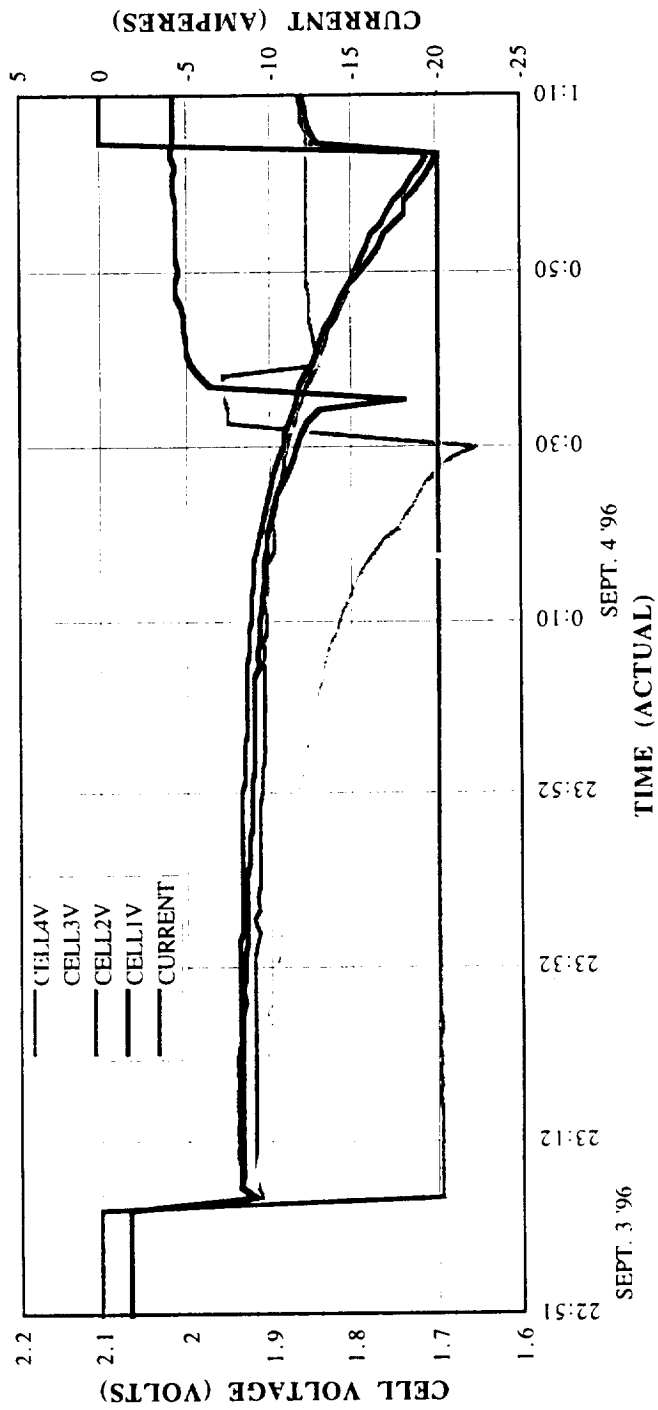


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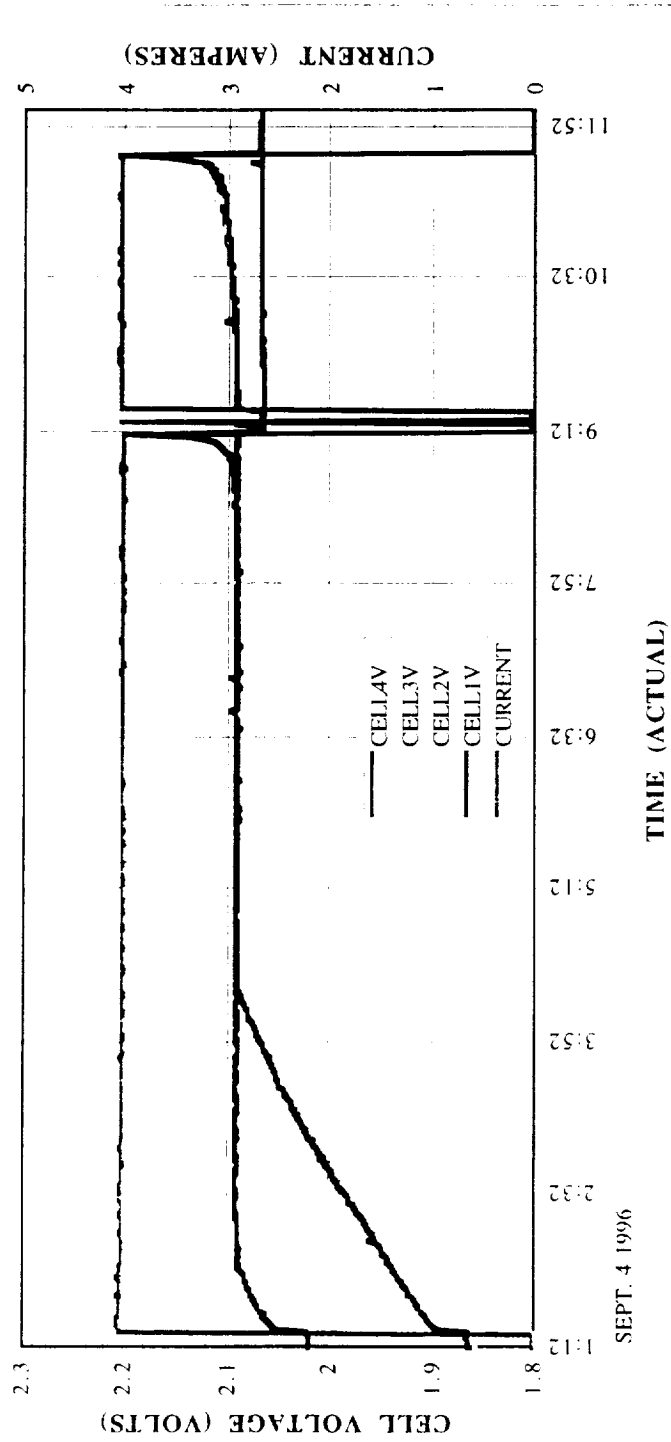
THERMAL VACUUM TEST DATA (-20 A DISCHARGE)

SODIUM SULFUR BATTERY CELL EXPERIMENT
 THERMAL VACUUM TEST 2-6 SEPTEMBER 1996
 CHARACTERIZATION CYCLE -20 AMP DISCHARGE



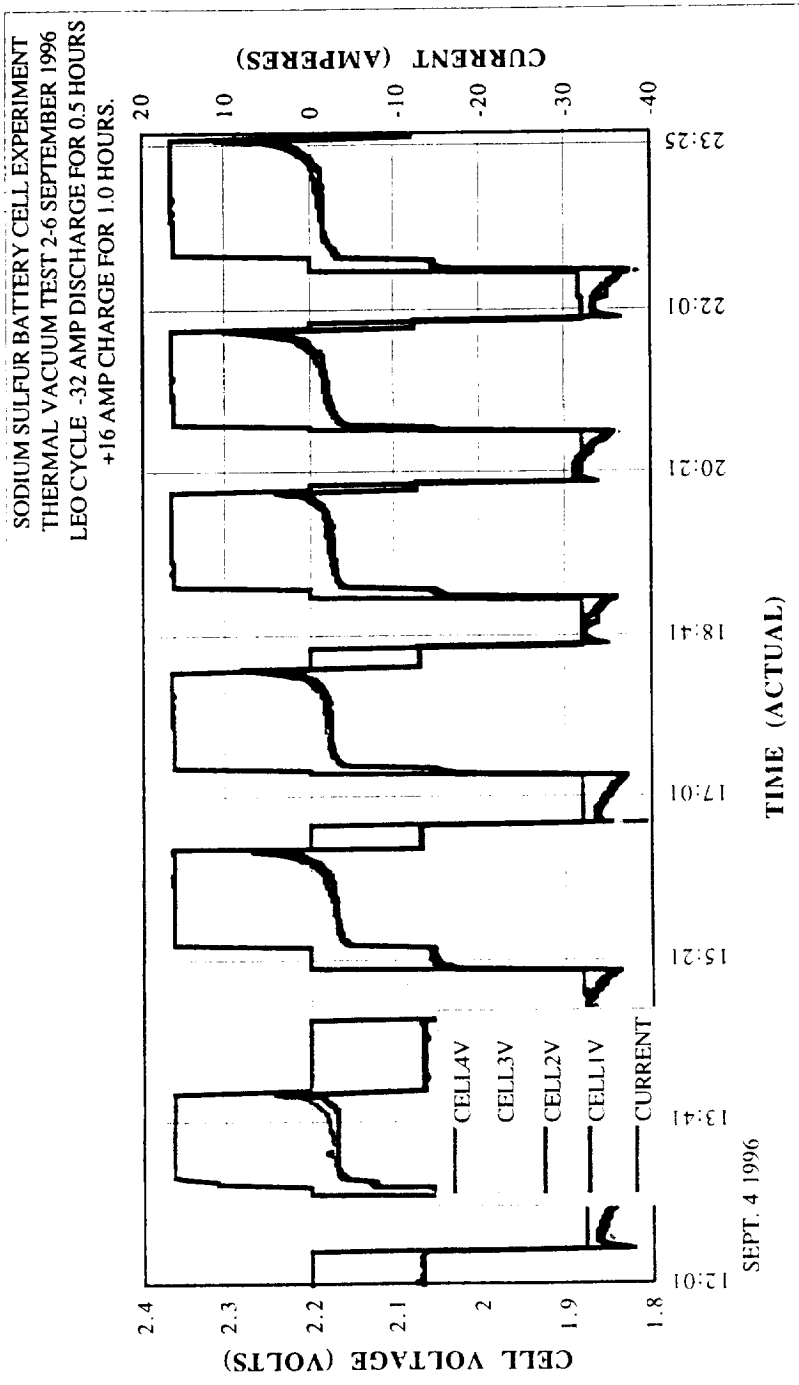
THERMAL VACUUM TEST DATA (4 A CHARGE)

SODIUM SULFUR BATTERY CELL EXPERIMENT
 THERMAL VACUUM TEST 2-6 SEPTEMBER 1996
 CHARACTERIZATION CYCLE 4.0 AMP CHARGE



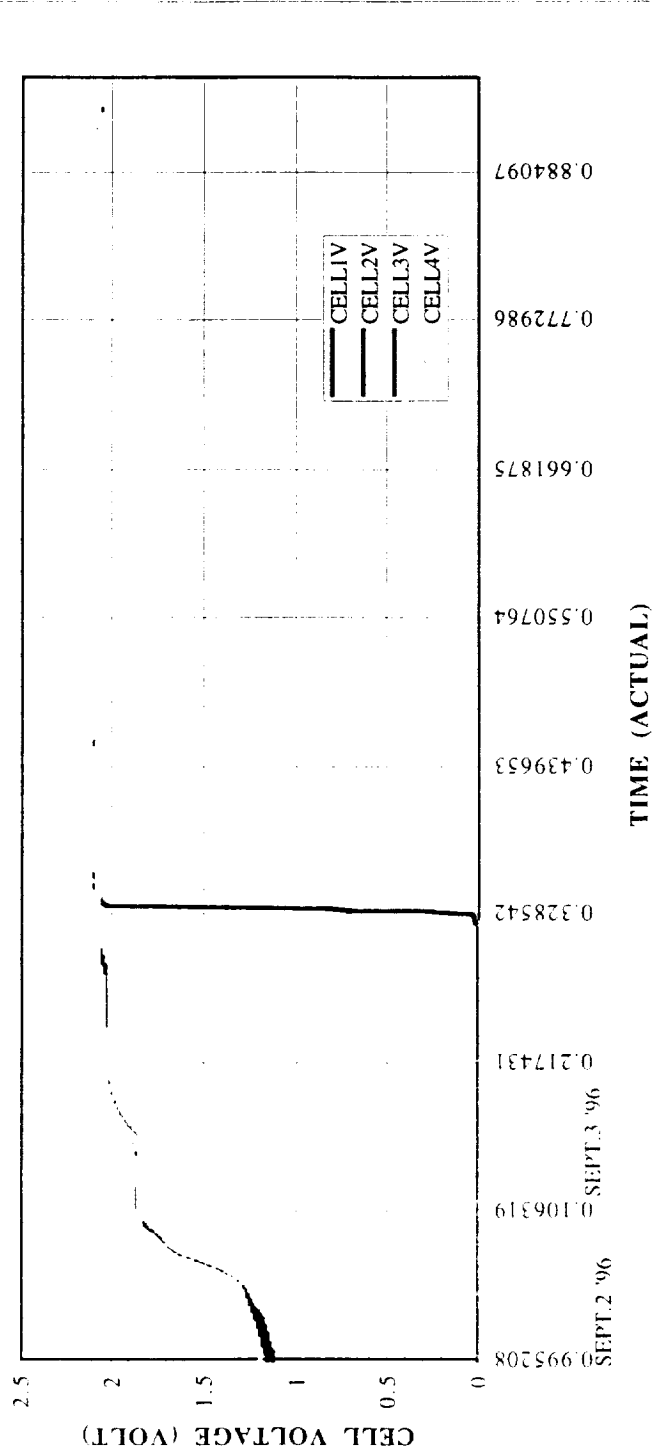
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THERMAL VACUUM TEST DATA (LEO 40% DOD)



THERMAL VACUUM TEST DATA

SODIUM SULFUR BATTERY CELL EXPERIMENT
THERMAL VACUUM TEST 2-6 SEPTEMBER 1996



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SUMMARY

- **USAF PL SPONSOR FOR NaS BATTERY CELL FLIGHT EXPERIMENT**
- **GROUND TESTS DATA SHOW NaS WITH SPECIFIC ENERGY >100 WH/KG**
- **EXPERIMENT MODIFICATION IN PROGRESS FOR RIDE AS NASA HITCHHIKER PAYLOAD**
- **NEGOTIATING FOR LAUNCHES ON STS -89, STS-90, AND STS-91**

