



## Development of a 70 Ah Li-ion Cell for Aerospace Applications

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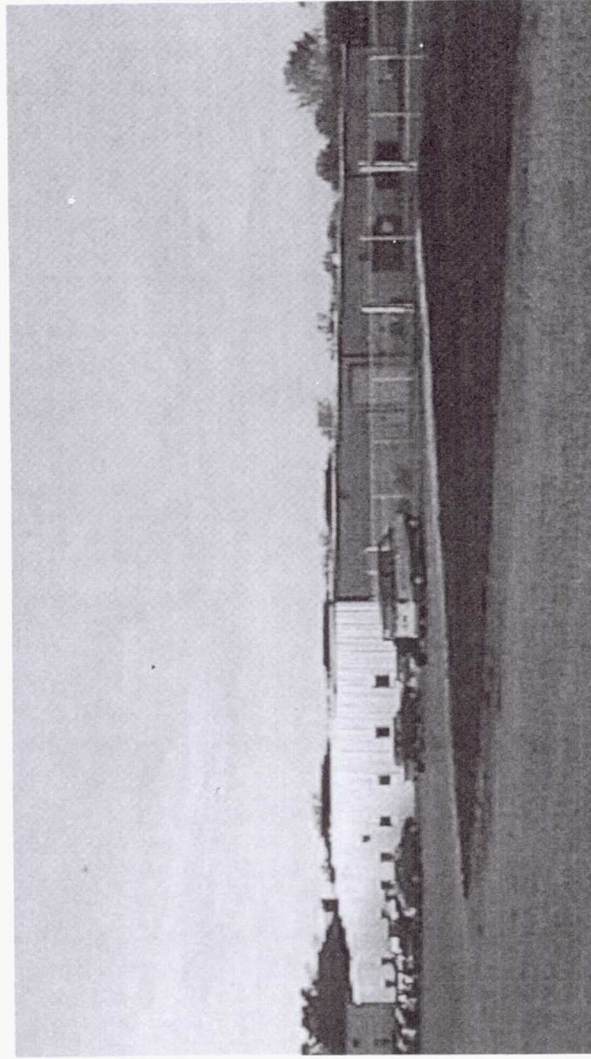


# Li-Ion Technology Center Joplin, Missouri

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- ◆ 20,000 ft<sup>2</sup> Total
- ◆ 15,000 ft<sup>2</sup> Mfg.
- ◆ 5,000 ft<sup>2</sup> Office
- ◆ Stand-alone Facility



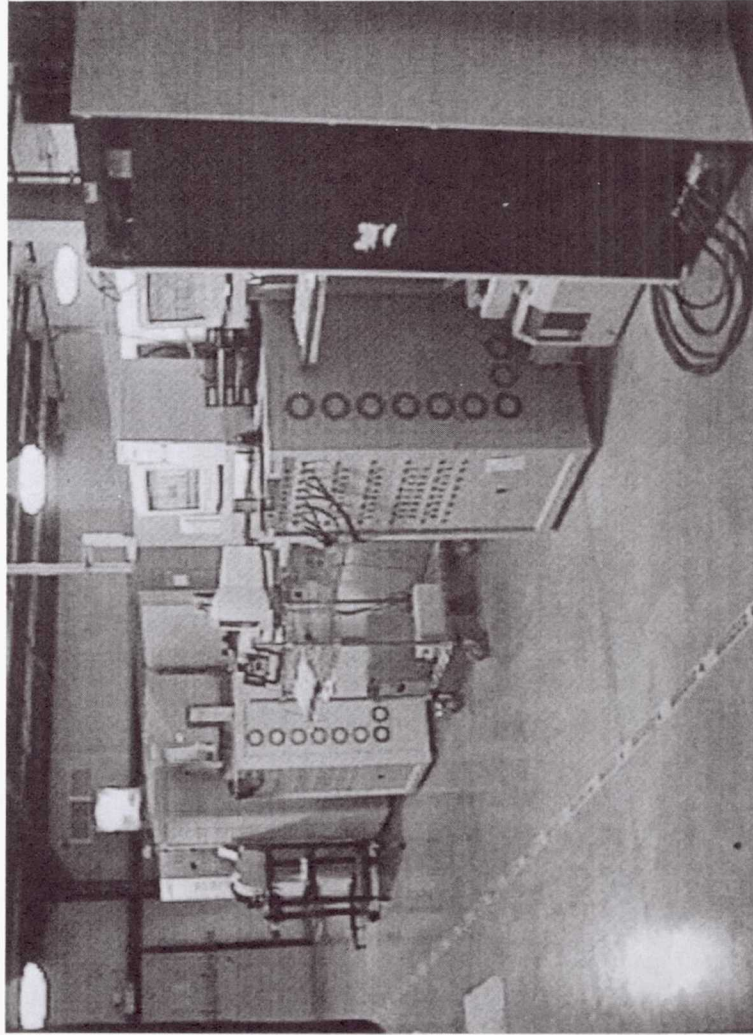
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## Lithium-Ion Test Area

- ◆ 300 cell capability
- ◆ 35 battery capability
- ◆ 200 amps
- ◆ 40 volts
- ◆ - 65°C to + 85°C

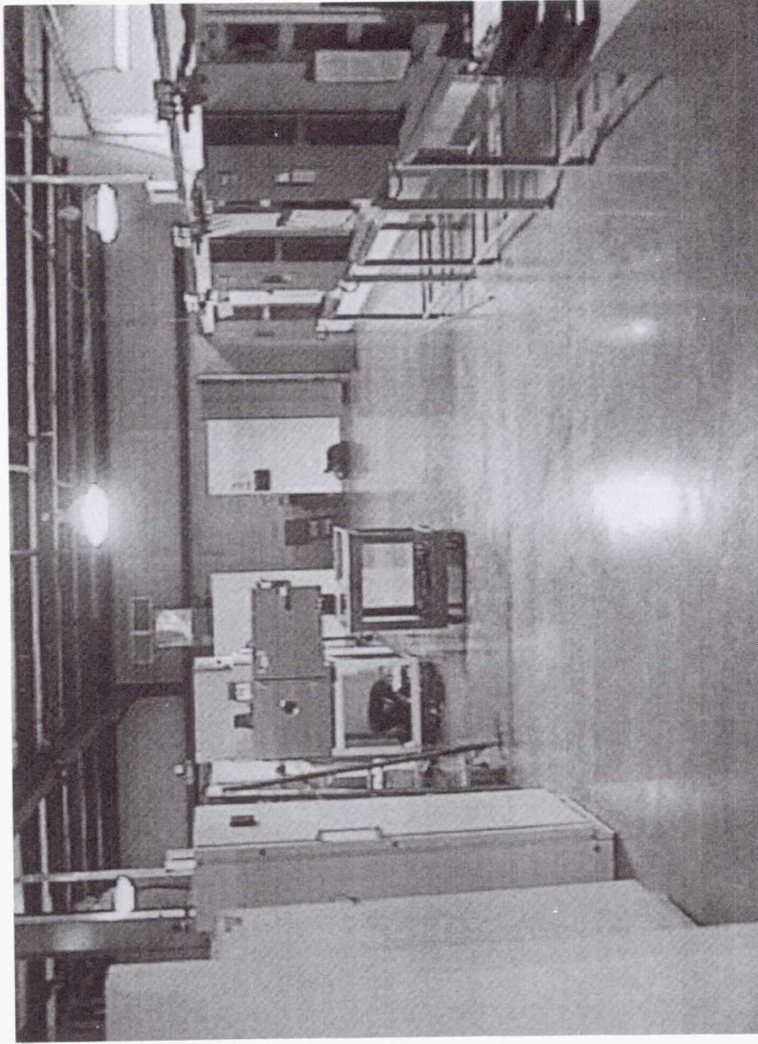


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## LEO Test Regime

- ◆ **Charge: 35 A - 60 min.**
  - No Taper Charge
  - Cut-off of 4.1 volts
- ◆ **Discharge: 70 A - 30 min.**
  - Cut-off of 3.0 volts
- ◆ **Temp. Stabilization**
  - 5 temperatures
  - 20 cycles/temperature
- ◆ **Pulse Tests**
  - $\pm 10A$ ,  $\pm 20A$ , &  $\pm 40A$



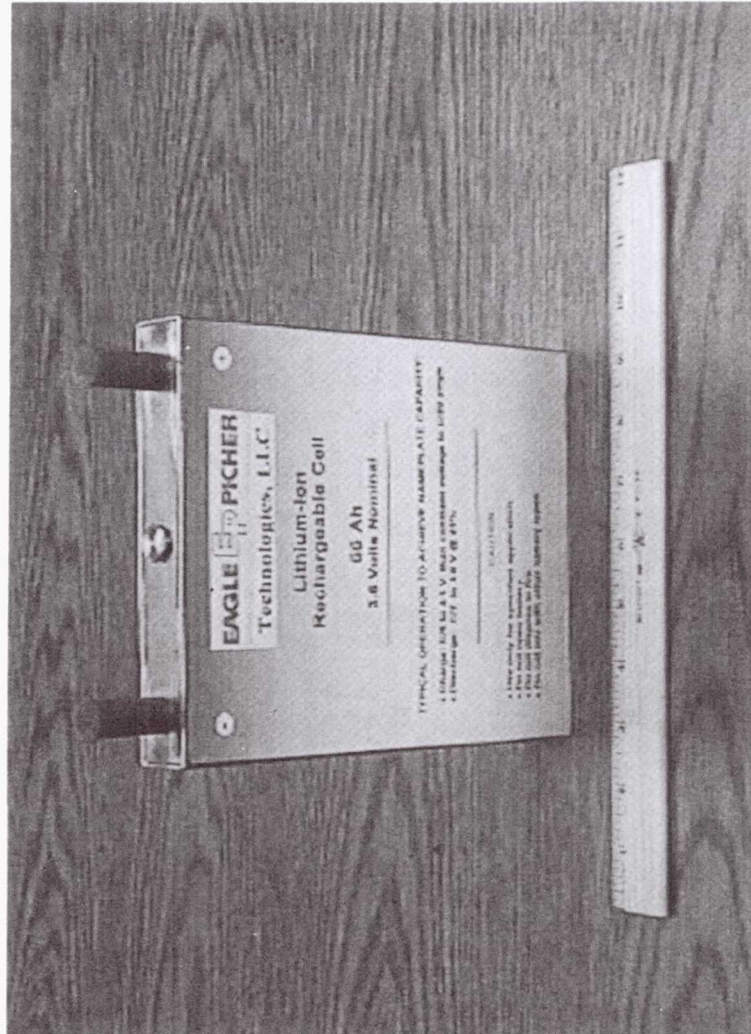
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## Li-Ion Aerospace Design

- ◆ SLC-16020 cell
- ◆ 66 Ah nameplate
- ◆ Size: 6.69" x 8.63" x 1.06"
- ◆ 3 cells in initial group
- ◆ 2 cells @ temperature range, 1 cell as control unit



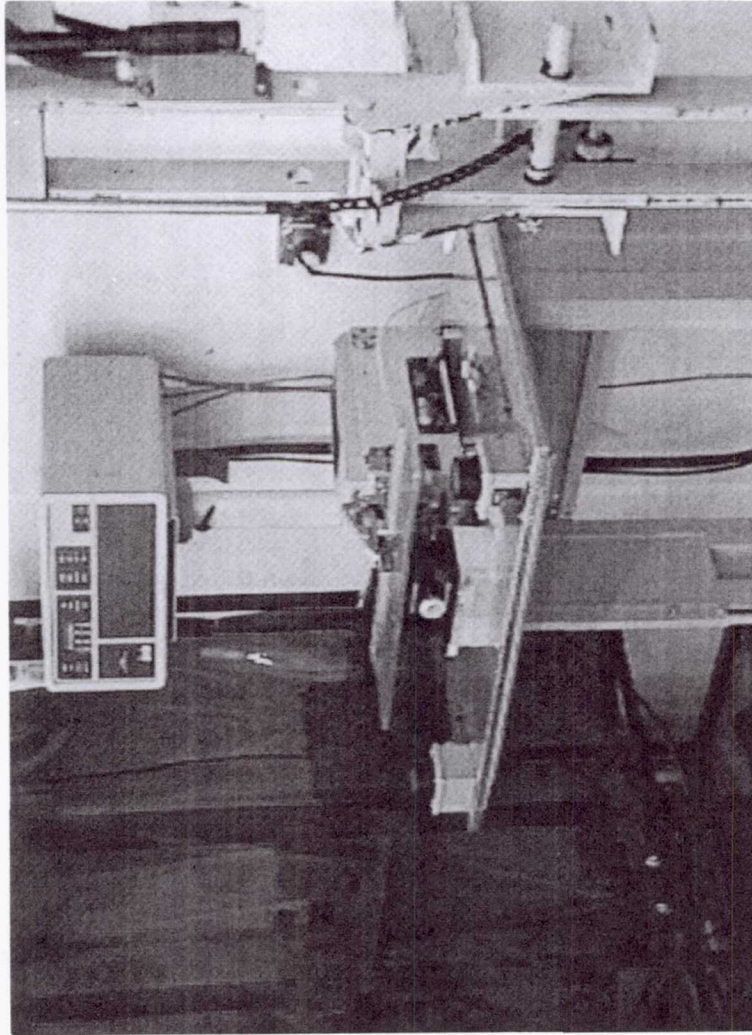
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## Cell Construction

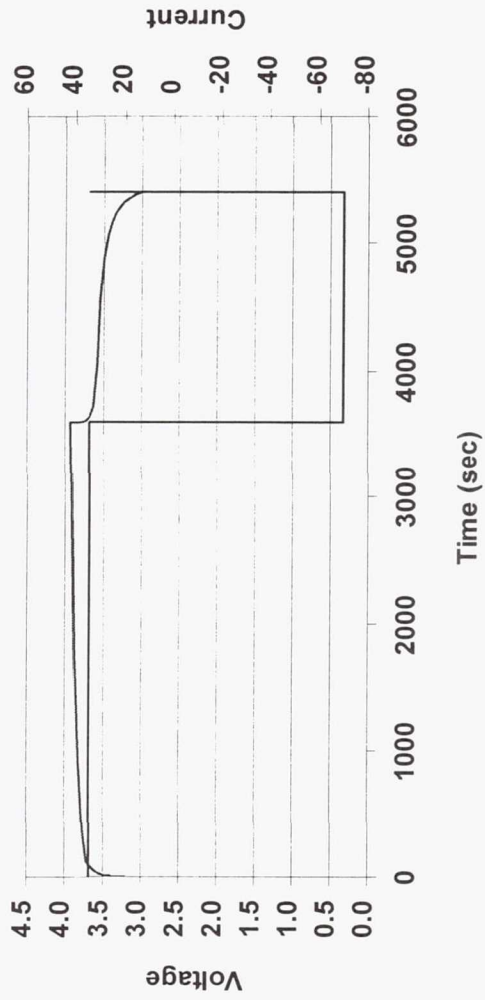
- ◆ Riveted header/tab
- ◆ 6 3/8" by 7 1/2" electrodes
- ◆ Ambient temperature electrolyte
- ◆ Conservative approach



# Typical Charge/Discharge @ + 23°C

- ◆ **23°C Performance**
  - Charge Capacity: 35.01 Ah
  - Discharge Capacity: 34.90 Ah
  - Full capacity achieved on LEO cycle

Charge: C/2 for 60 Minutes - No Taper Charge  
Discharge: C for 30 Minutes

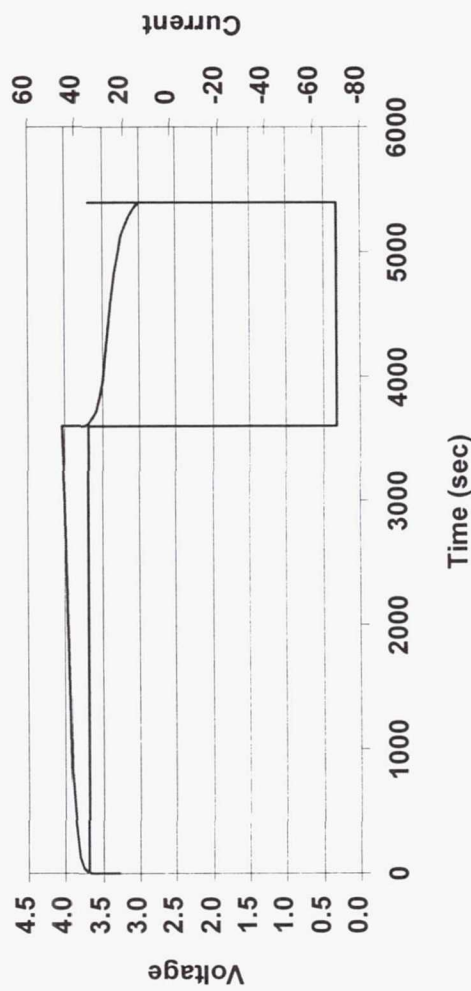


# Typical Charge/Discharge @ +10°C

## ◆ 10°C Performance

- Charge Capacity: 35.01 Ah
- Discharge Capacity: 34.83 Ah
- Achieved full capacity on LEO cycle

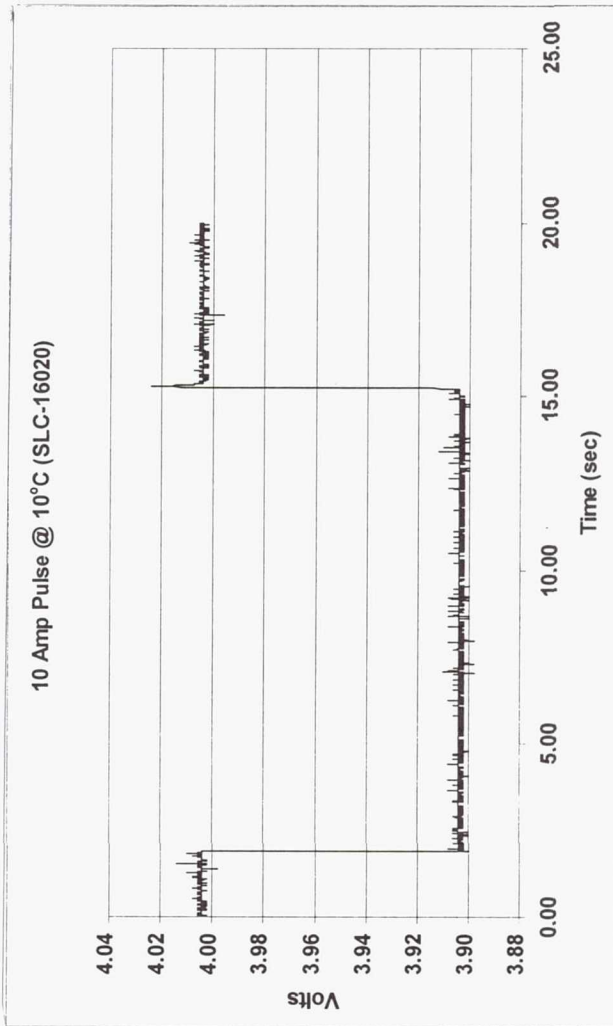
Charge: C/2 for 60 Minutes - No Taper Charge  
Discharge: C for 30 Minutes





# Pulse Test Data @ 10°C

- ◆ Impedance measurement conducted during charge and discharge

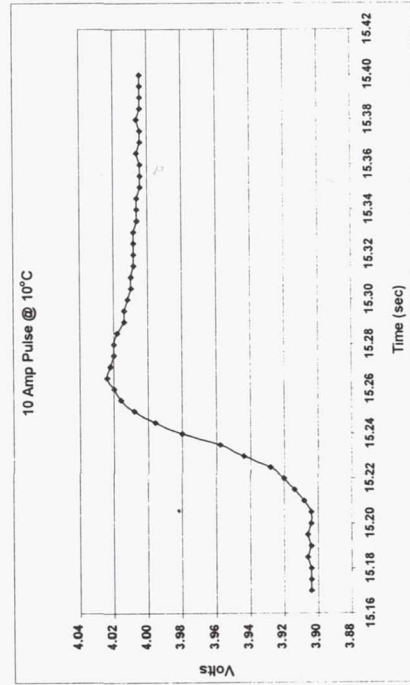
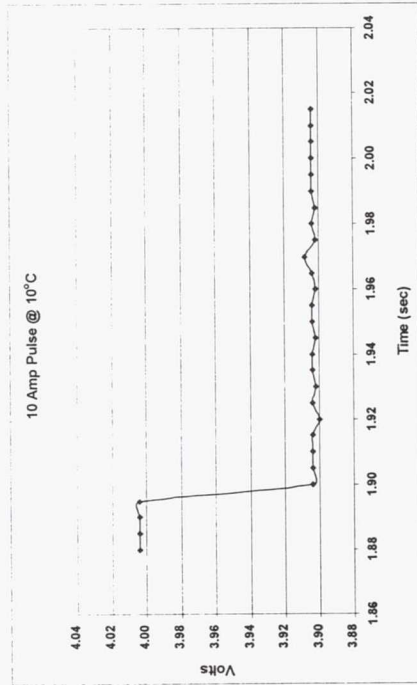


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# Pulse Test Data @ 10°C

- ◆ 10 amp pulse
- ◆ Rise time approx.  
0.00004

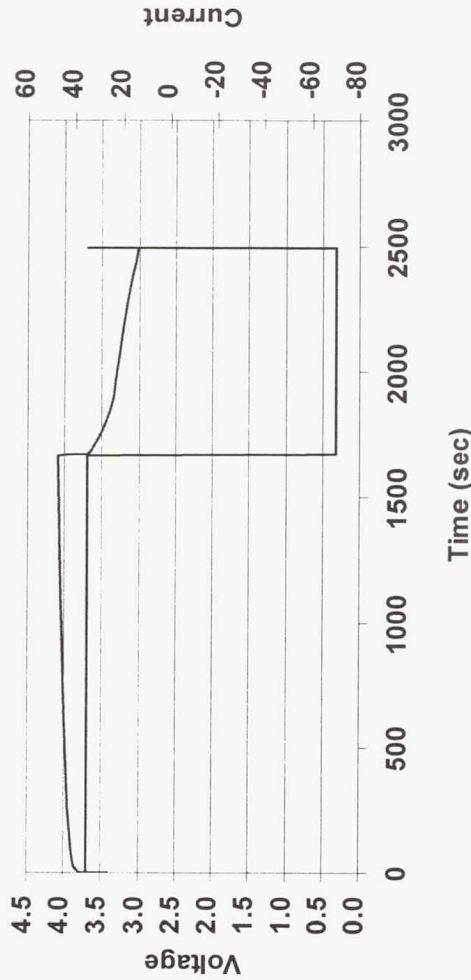


# Typical Charge/Discharge @ + 5°C

## ◆ 5°C Performance

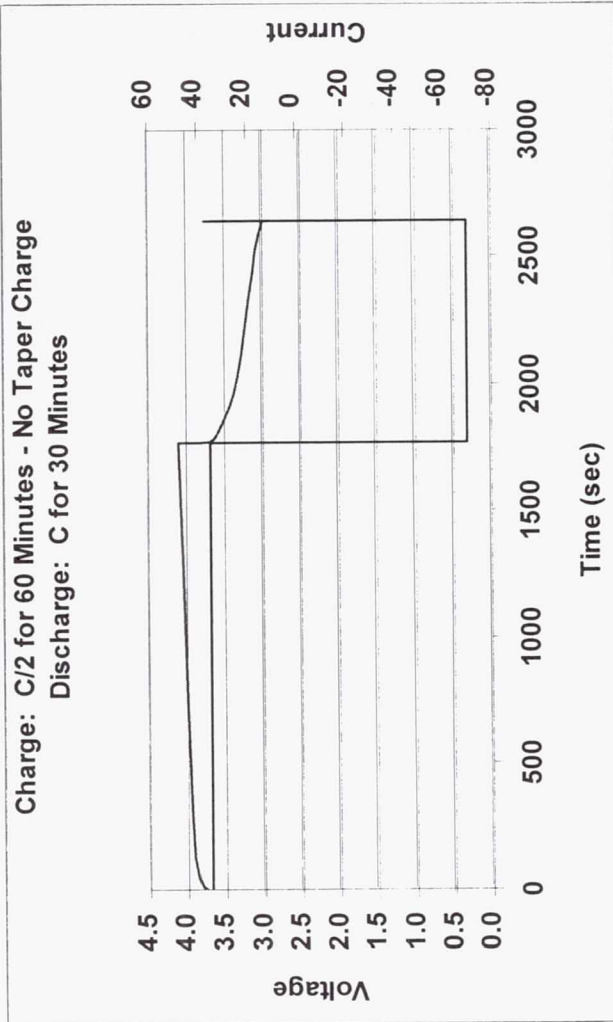
- Charge Capacity: 16.22 Ah
- Discharge Capacity: 16.06 Ah
- Discharge/Charge Efficiency > 99%
- Achieved 25% Depth of Discharge

Charge: C/2 for 60 Minutes - No Taper Charge  
Discharge: C for 30 Minutes



# Typical Charge/Discharge @ 0°C

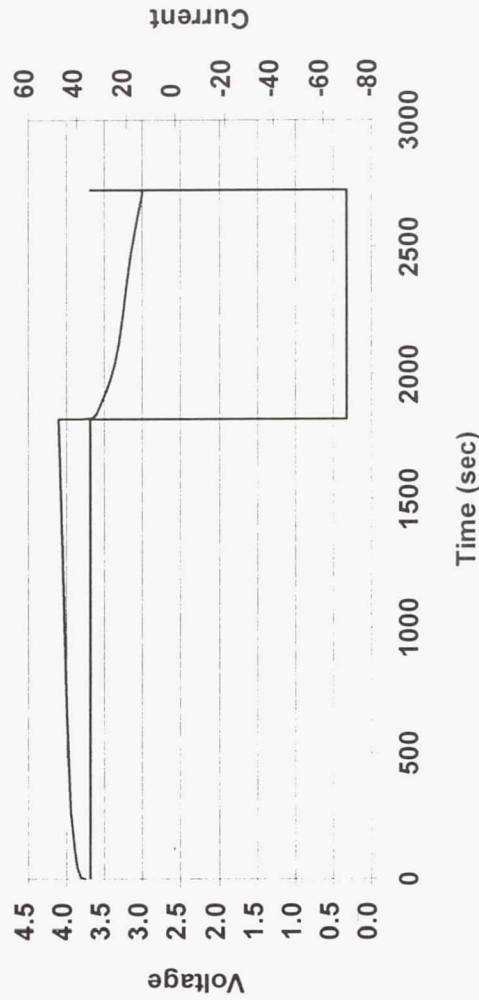
- ◆ **0°C Performance**
  - Charge Capacity: 17.20 Ah
  - Discharge Capacity: 16.97 Ah
  - Performance same as 5°C Data:
    - Efficiency >99%
    - Achieved 25% DOD



# Typical Charge/Discharge @ -5°C

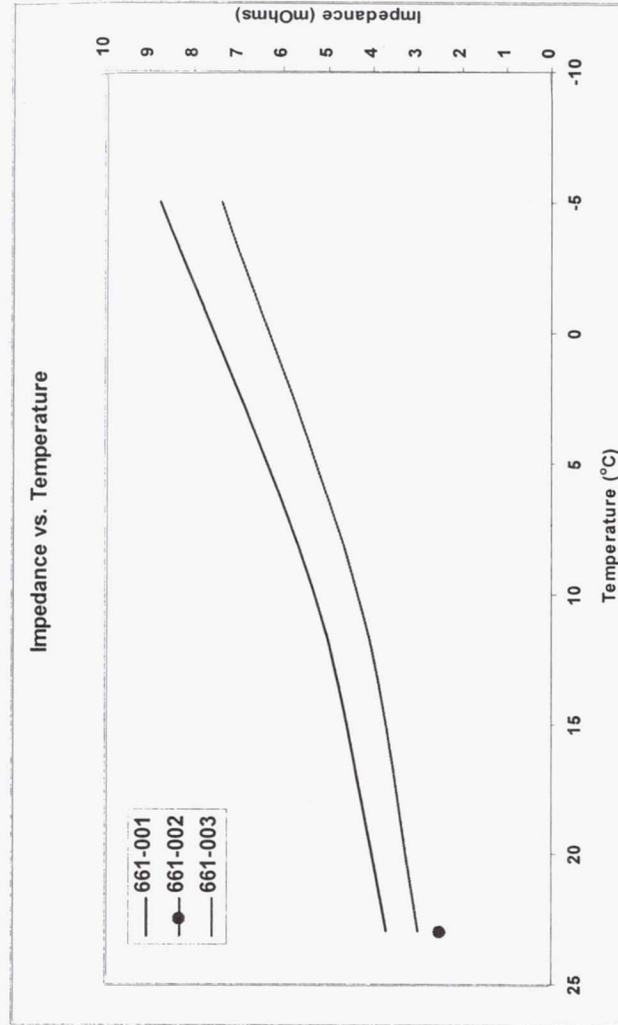
- ◆ **-5°C Performance**
  - Charge Capacity: 17.71 Ah
  - Discharge Capacity: 17.52 Ah
  - Met requirements of LEO test regime

Charge: C/2 for 60 Minutes - No Taper Charge  
Discharge: C for 30 Minutes



# Calculated Impedance

- ◆ Control cell 661-002 was subjected to same cycling tests as cells 001 and 003 at a constant temperature of 23°C
- ◆ Control cell showed no increase in impedance

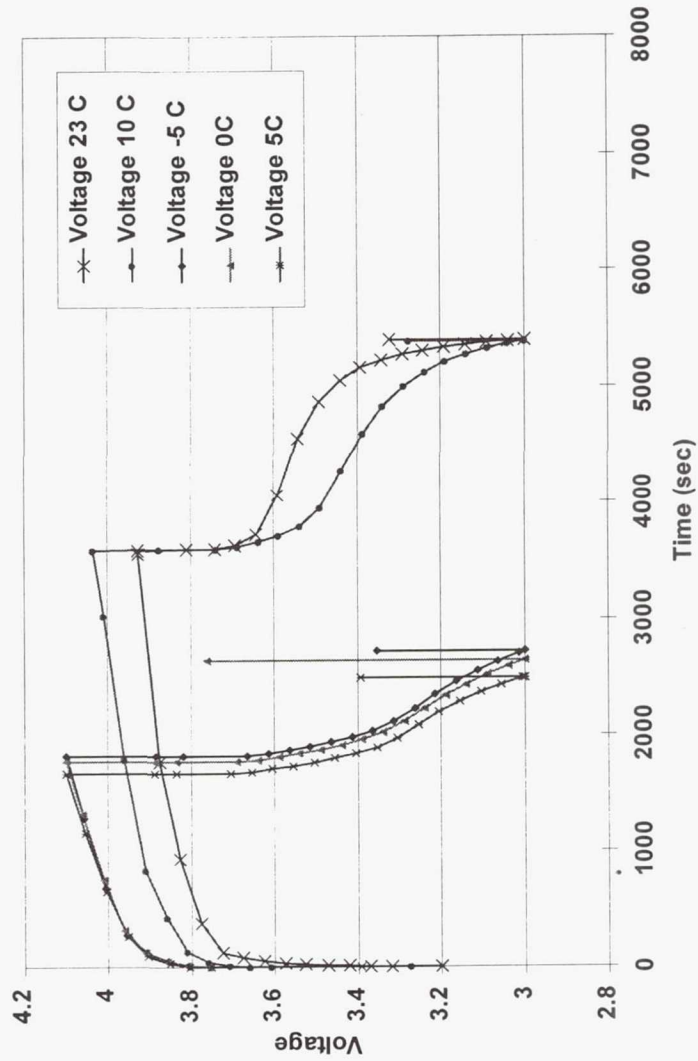


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# Typical Charge/Discharge for Cell #003 from -5°C to +23°C

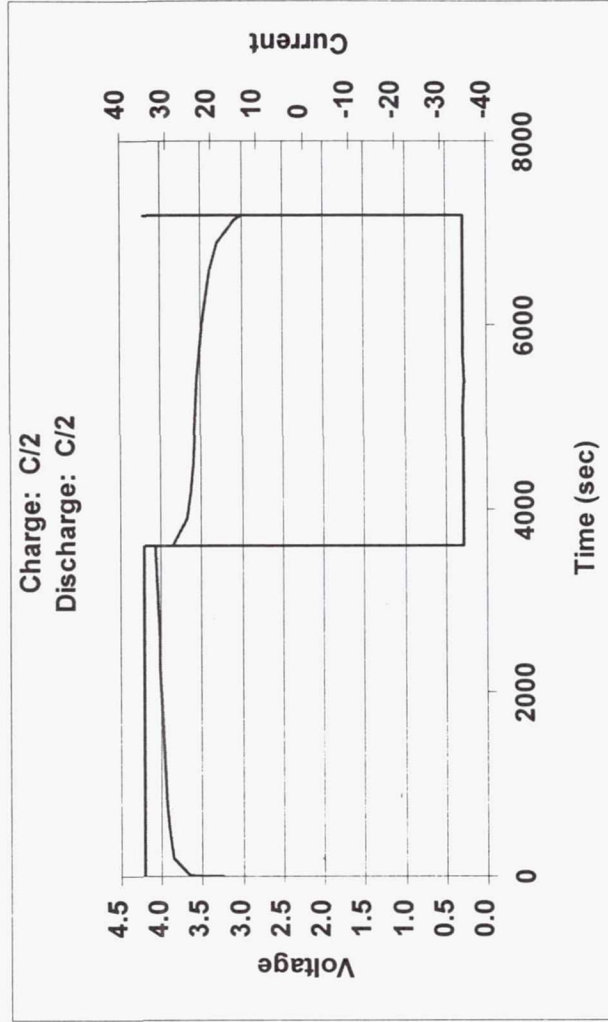
- ◆ Effects of temperature on cell performance
- ◆ From 10°C to 23°C full capacity (50% DOD) at C rate
- ◆ From -5°C to +5°C, 25% DOD achieved at C rate



# Typical Charge/Discharge @ 23°C (C/2 Charge & C/2 Discharge)

◆ **23°C Performance  
after 120 cycles over  
temperature range**

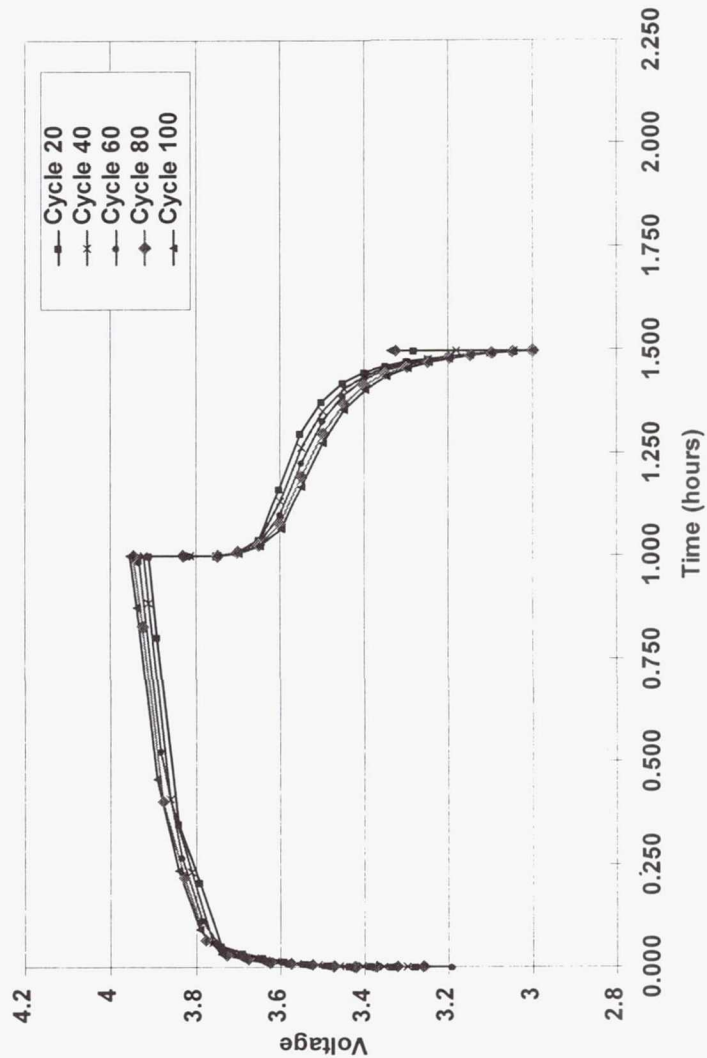
- Charge Capacity:  
35.01 Ah
- Discharge Capacity:  
34.93 Ah





# Typical Charge/Discharge of Control Cell @ 23°C

- ◆ **Cycles 1-100:**
  - C/2 Charge (35 A)
  - C Discharge (70 A)
- ◆ **Consistent @ 23°C**



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## Conclusion

- ◆ Initial cell group performance very good
- ◆ Demonstrated LEO rates to 50% DOD
- ◆ Demonstrated -5°C to +23°C performance
- ◆ Demonstrated C discharge and C/2 charge
- ◆ Demonstrated 99+% efficiency at LEO rates
- ◆ Demonstrated low impedance



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## Near Future Activities

- ◆ Ultrasonic weld header/tab connection
- ◆ Incorporate alternate electrolyte
- ◆ Reduce number of electrodes
- ◆ Optimize anode and cathode
- ◆ Conduct cycle life tests

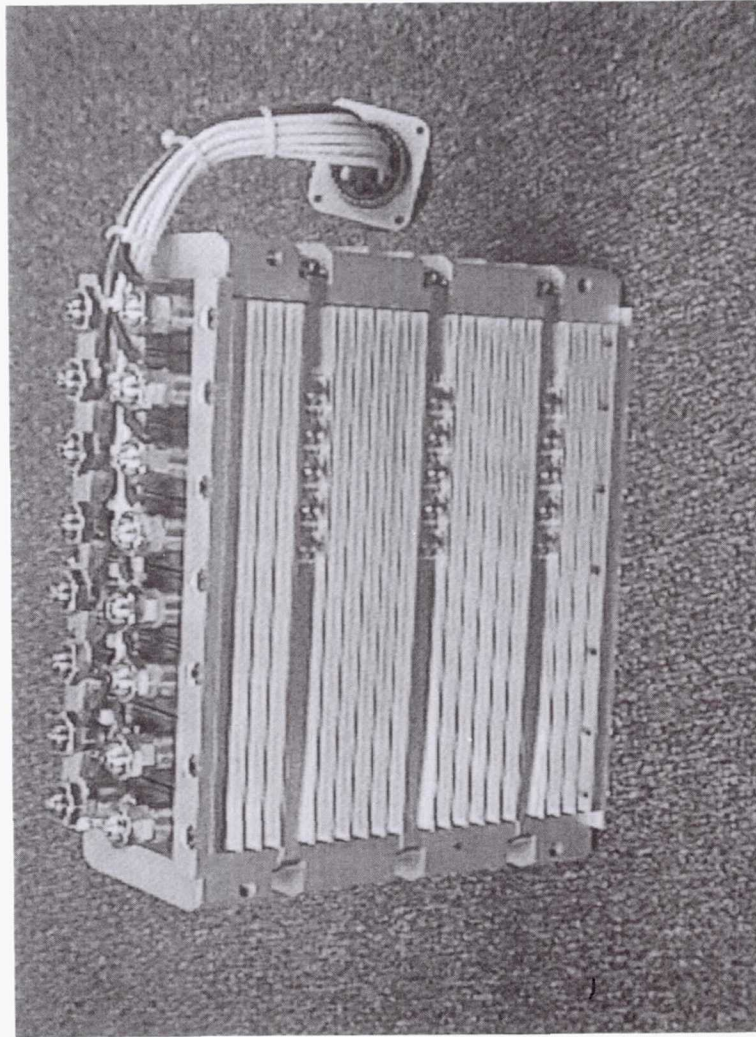


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## Acknowledgements

- ◆ Air Force & NASA & government organizations for financial support & technical guidance



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