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# NASA/GSFC Testing of Li-Ion Cells: Update

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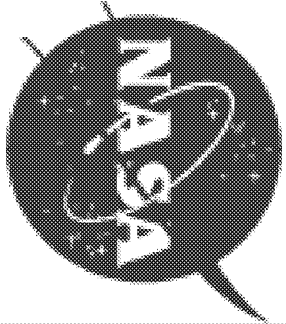
NASA-Goddard Space Flight Center

Greenbelt, Maryland

2000 NASA Aerospace Battery Workshop

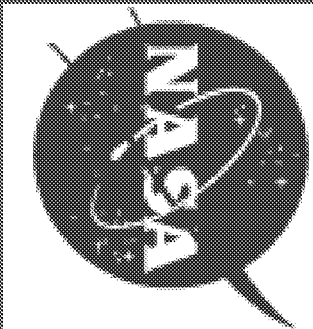
Huntsville, Alabama

November 14-16, 2000



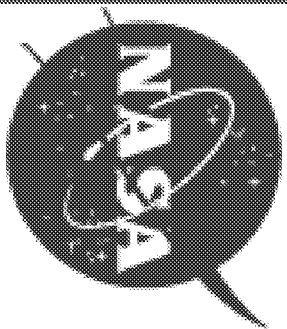
## Objective

- Cell Characterization
  - Capacity
  - Self-discharge
  - Mid-discharge voltage
- Determination of Cycling Performance as a Battery Pack under IEO regime
  - Number of cycles
  - Charge voltage
  - Temperature



## Cells Under Study

- Prismatic Cells
  - 20 AH Yardney
  - 1.5 AH Wilson Greatbatch
- Cylindrical Cells
  - 12 AH, 4 AH and 1.25 AH SAFT
- Polymer cells
  - 3 AH Alliant Tech.
  - 8 AH Lithium Technology, Inc.



## Characterization Data

- Self-discharge - 72 hours charged open-circuit stand
  - Yardney = 1.4%
  - SAFT = 1.4%
  - Alliant Tech (ATK) = 2%
  - Wilson Greatbatch (WG) = 1.4%
- Capacity Decrease when the discharge rate is increased to C/2 from C/5
  - Yardney - 2%
  - SAFT - 0.9%
  - ATK - 2%
  - WG - 25%





## Characterization Data -Contd.

- Mid-discharge voltages at C/2 discharge rate
  - Yardney = 3.51V
  - SAFT = 3.56V
  - ATK = 3.54 V
  - WG = 3.65V
- Cell impedance (mohms) at 50% SOC
  - SAFT = 1.74
  - Yardney = 10.2
  - ATK = 51
  - WG = 68



## Characterization Data -Contd.

- Capacity at 0°C in percentage of capacity at 25°C
  - Yardney = 92%
  - SAFT = 91%
  - WG = 91%
  - ATK = 51%



## LEO Cycling: Conditions

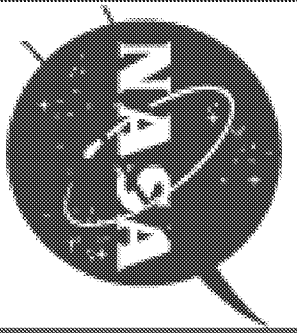
- Continuous cycling in a regime consisting of 30 min. discharge and 60 min. charge at the rate of 16 cycles/day
- Temperature =  $-20^{\circ}\text{C}$  to  $40^{\circ}\text{C}$
- Depth of discharge = 40%
- Charge voltage clamped at a Battery/Pack voltage at  $C/2$  rate with current taper
- Recharge ratio = 1-1.01



# LEO Cycling: Data

Number of cells and cell type	CAP, AH AT 25°C	Charge V/limit	CYCLES	STATUS
8 - SAFT 12AH	11.4	3.85	2745	Continuing
8 - Yardney 20AH*	24.9	4	2739	Continuing
5 - Alliant Tech 3AH	2.06	4	2359	Discont'd
8 - WG 1.5AH	1.43	4.1	10	Discont'd
8 - Li-Tech 8AH	7.1	4.1	2	Discont'd
2 - SAFT 4AH	4	3.85	7472	Continuing
2 - SAFT 1.25AH	1.3	3.85	11323	Continuing

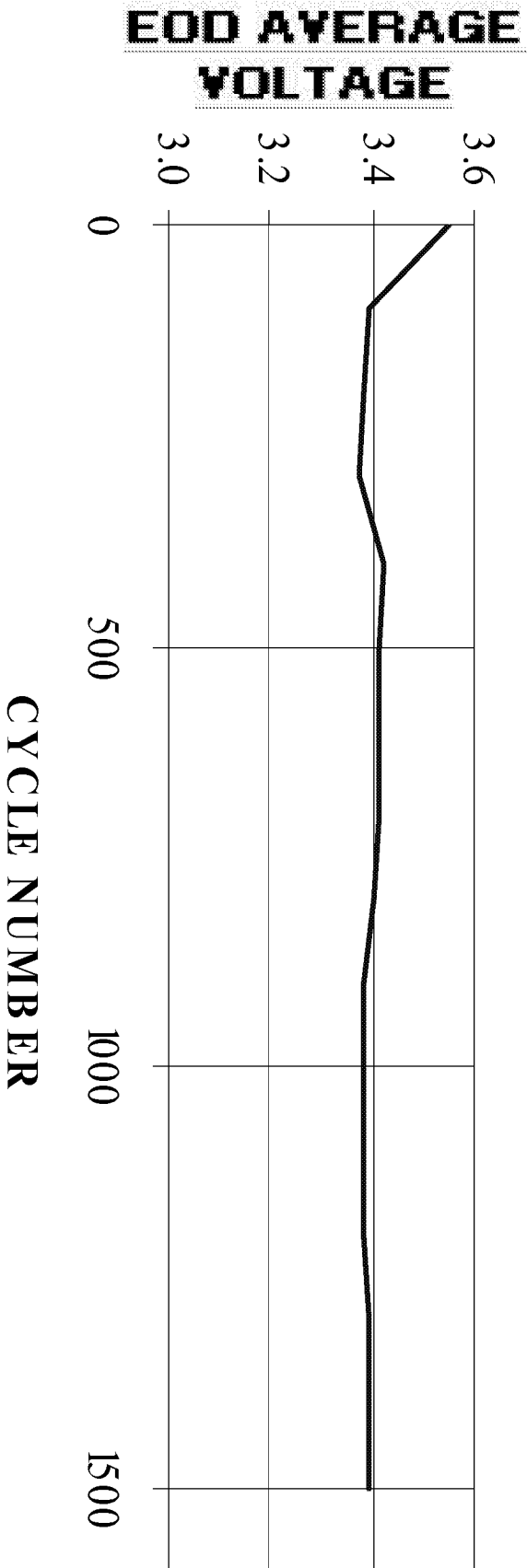
\*Cells 192, 194, 195 and 196 have previously completed 2966 cycles.

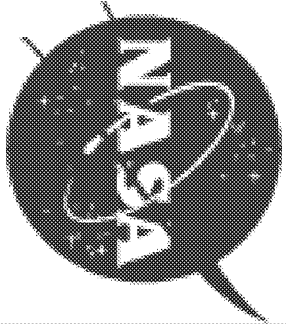


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### VARIATION OF EOD VOLTAGE FOR SAFT 12 Ah CELLS AT 20°C, 3.85V LIMIT

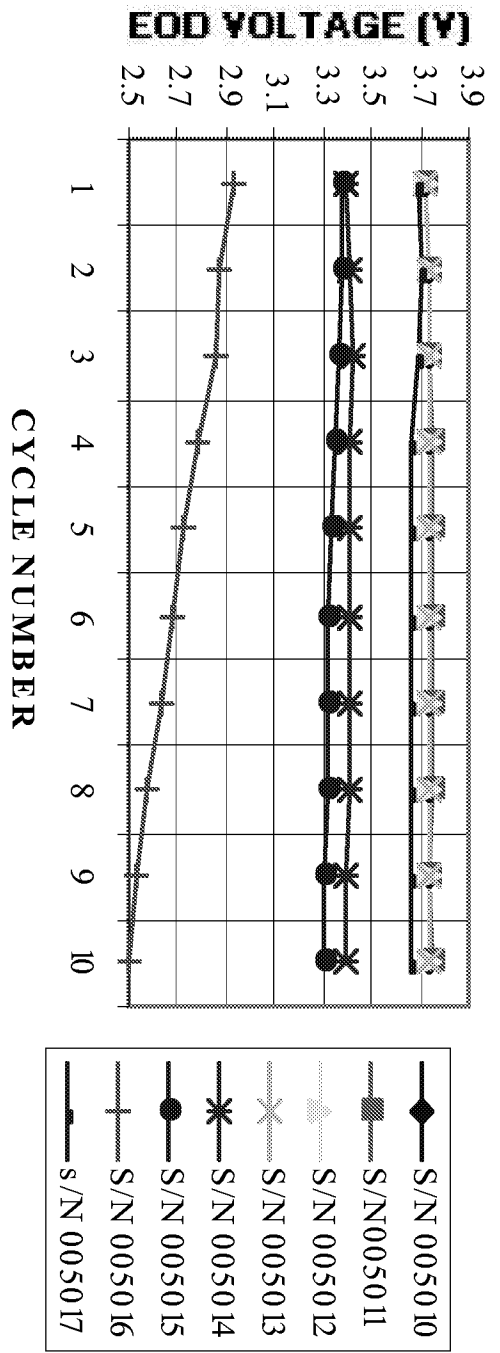


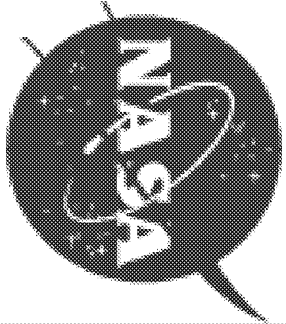


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VARIATION OF END OF DISCHARGE VOLTAGE WITH CYCLING FOR WG CELLS AT 20°C, 4.1 V LIMIT

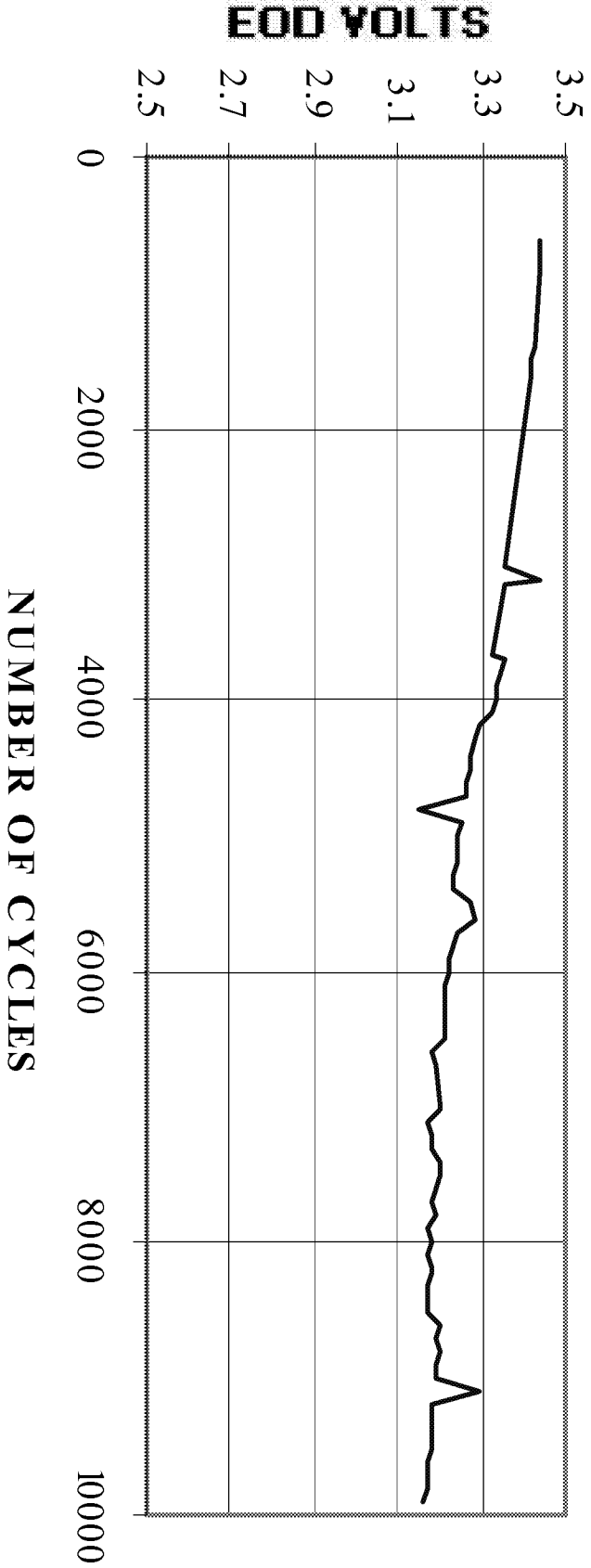




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**VARIATION OF EOD WITH CYCLING FOR SAFT 1.25 AH  
CELL AT 30°C, 3.85V LIMIT**





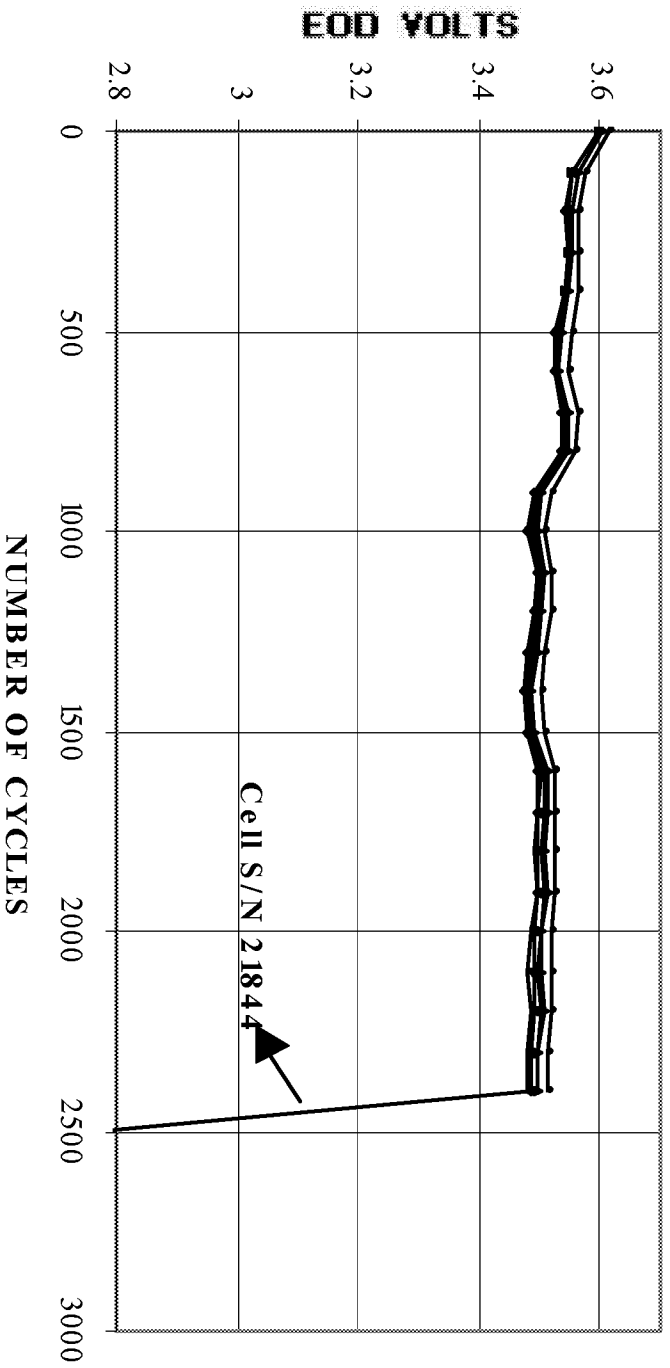


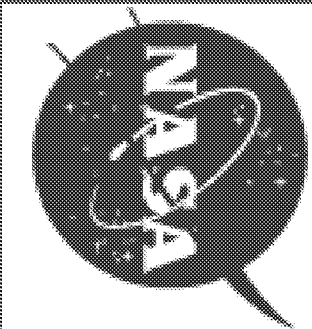


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VARIATION OF EOD VOLTAGE WITH CYCLING FOR ALLIANT  
TECH 3 AH CELLS AT 20°C, 4V LIMIT



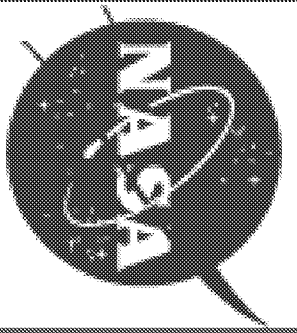


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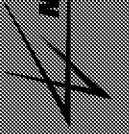


## PERFORMANCE TWO 2-CELL SAFT 4 AH BATTERIES

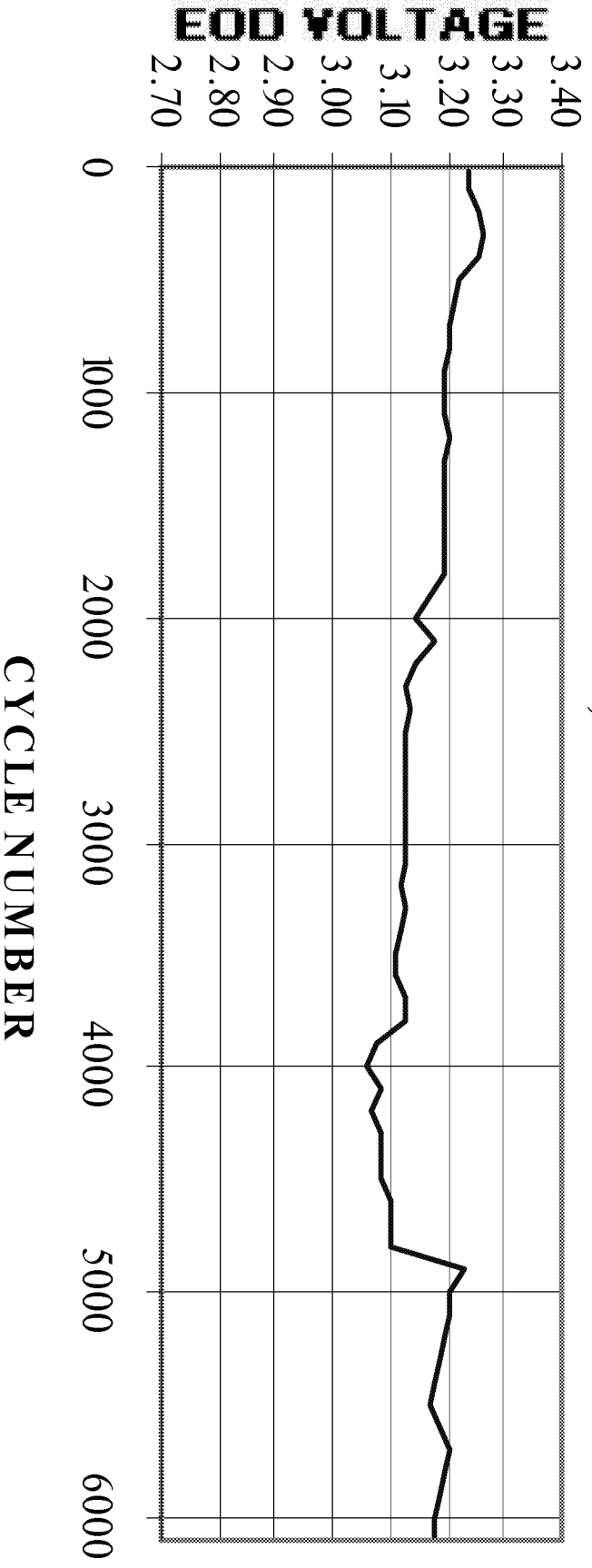
Temp °C	Number of cycles	End of dischg voltage	Comments
30	4289	3.217	cell charged to 3.85V
40	550	3.266	cell charged to 3.85V
0	560	2.816	cell charged to 4.1V
-20	2	2	cell charged to 4.3V
-10	39	2.755	cell charged to 4.48V
10	442	3.039	cell charged to 4.1V
20	6157	3.17	cell charged to 3.85V



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**VOLTAGE BEHAVIOR DURING CYCLING FOR SAFT  
4AH CELLS  
20°C, 3.85 V LIMIT**



## Conclusions

- The self-discharge rate of Li-ion cells is 1.4% in the 72-hr charged open-circuit stand test that is superior to NiCd and NiH<sub>2</sub> Batteries
- Charge acceptance of the cells decreases with temperature
- Cells cannot be cycled in a 90-minute orbit and 40% DoD at minus 10°C unless the voltage limit on charge is increased to 4.5V
- Limited cycling excursion to minus 20°C (low temperatures) does not appear to impair the cycling behavior at 20°C
- The solid electrolyte and gel electrolyte cells' performance is inferior to the liquid electrolyte cells under our LEO test conditions
- The data suggests the potential use of a battery level charging by monitoring and managing the cell parameters