

# Lithium-Ion Verification Test Program

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# Li-Ion Verification Test Program

- Need for technology verification for aerospace applications
- Structure flexible program that will allow assessment of current technology capabilities
- Provide information about various vendors
- Provide for assessment of technology developments
- Developed statistical DOE to interpret relationships in data and to address program test goals and resource limitations
- Data will be used to develop a model to predict life of cells as a function of DOD, temperature, and EOCV

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# Li-Ion Verification Test Program

- Purchased 40 cells from two vendors
  - 40 Ah SAFT (10 additional cells at MSFC)
    - G4 chemistry space cells (HE54245)- Lithiated Nickel Oxide based cathode with Graphite based anode using carbonate solvents +  $\text{LiPF}_6$  electrolyte
  - 30 Ah Lithion (10 additional cell at MSFC)
    - INCP 95/28/154 - Lithiated Nickel Cobalt Oxide cathode with Graphite anode using EC:DMC:DEC electrolyte
- Will be receiving 40 cells from MSA (50 Ah) at the end of the year
- Small cell concept under consideration



# Li-Ion Verification Test Program

- **Test Variables**

- Vendor: SAFT, Lithion, MSA
- Depth of Discharge: 20, 30, 40% for Yardney & MSA; 20, 30, 35% for Saft
- Test Temperature: 10°C, 20°C, 30°C
- End of Charge Voltage: 3.85V, 3.95V, 4.05V
- Cell test conditions based on average actual discharge capacity from 4.1 V to 3.0 V at C/2 and 20°C

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# Li-Ion Verification Test Program

- Individual cells electrically assembled into 4 cell packs at ten test conditions
- Cells randomly assigned to packs
- Packs randomly assigned to conditions
- Average Capacity
  - Saft: 45.9 Ah
  - Lithion: 32.7 Ah
- LEO testing at 20°C started September, 2004 at NSWC/Crane, rest of testing will start in November, 2004

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# Li-Ion Test Charge Control

- Charge control circuitry – addresses cells individually
  - Clamp individual cell voltage as each cell reaches limit with cell charge control circuit that bypasses excess current and allows current to taper
  - When all cells reach limit, taper pack current by smallest cell bypass current
  - Continue for the time allotted for charge
- Charge control hardware developed and built at GRC
- Charge control software developed and implemented by NSWC/Crane to minimize bypassed current and heat generation



# Li-Ion Cell Test Matrix

Temp(°C)	Voltage	DoD	Lab
30	4.05	20	GRC
30	3.85	20	GRC
10	3.85	20	GRC
30	3.95	30	GRC
20	3.95	20	GRC
10	3.85	40 <sup>1</sup> /35 <sup>2</sup>	GRC
20	3.85	30	GRC
30	3.85	40 <sup>1</sup> /35 <sup>2</sup>	GRC
20	4.05	40 <sup>1</sup> /35 <sup>2</sup>	GRC
10	4.05	30	GRC
30	4.05	40 <sup>1</sup> /35 <sup>2</sup>	MSFC
10	4.05	20	MSFC

1 - Lithion, MSA

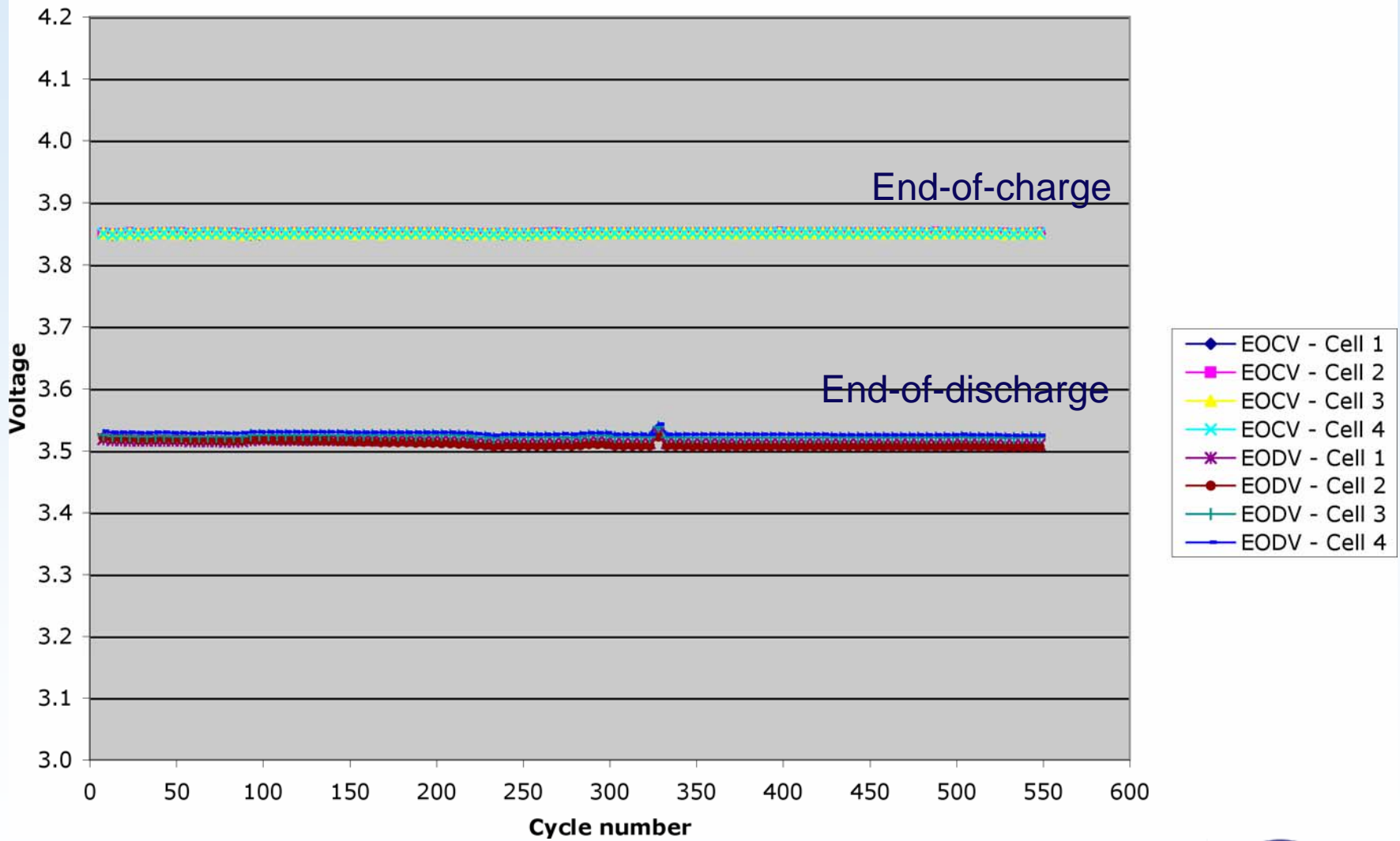
2 - Saft

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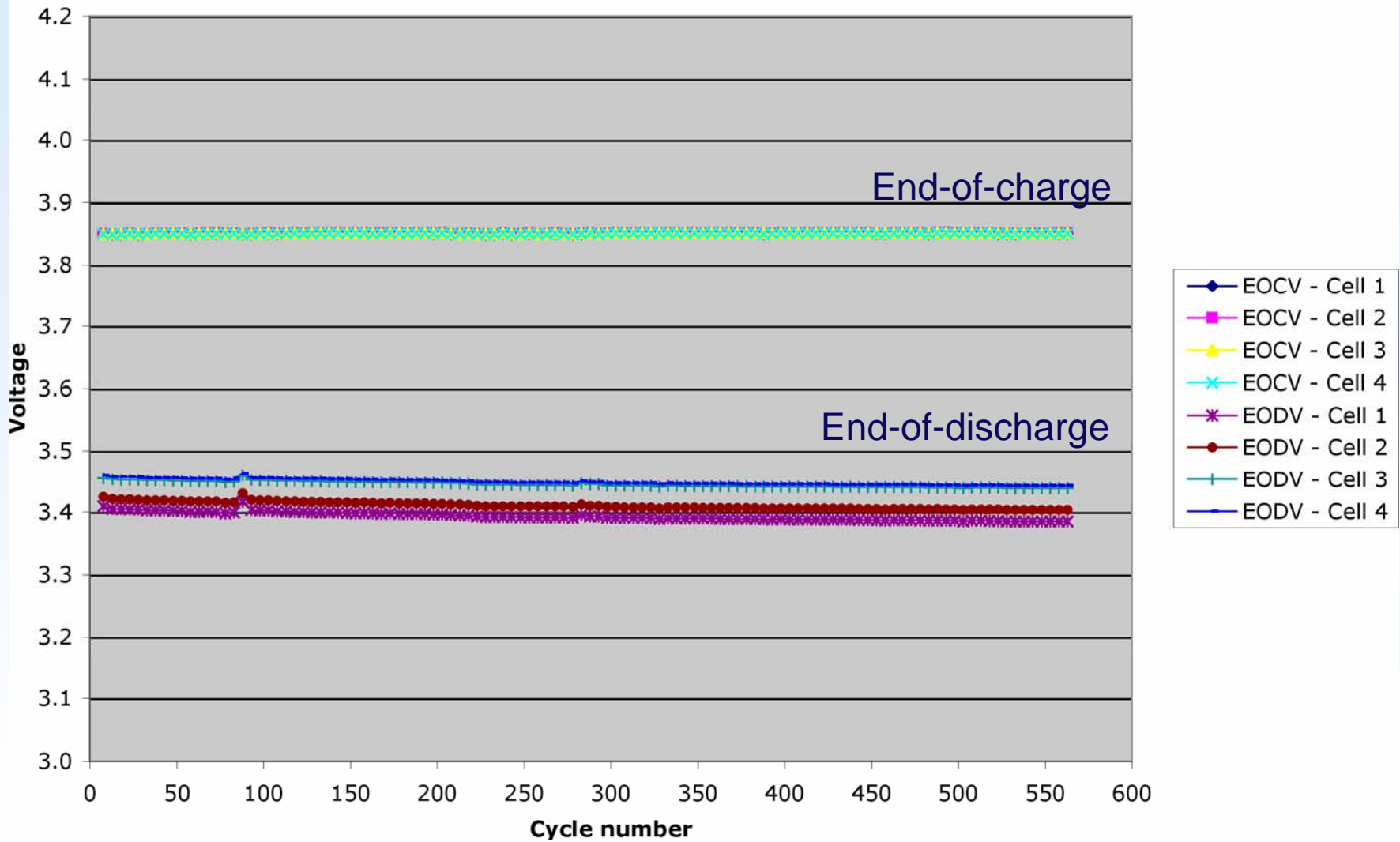


### Soft cells 3.85 EOCV, 20°C, 30% DOD

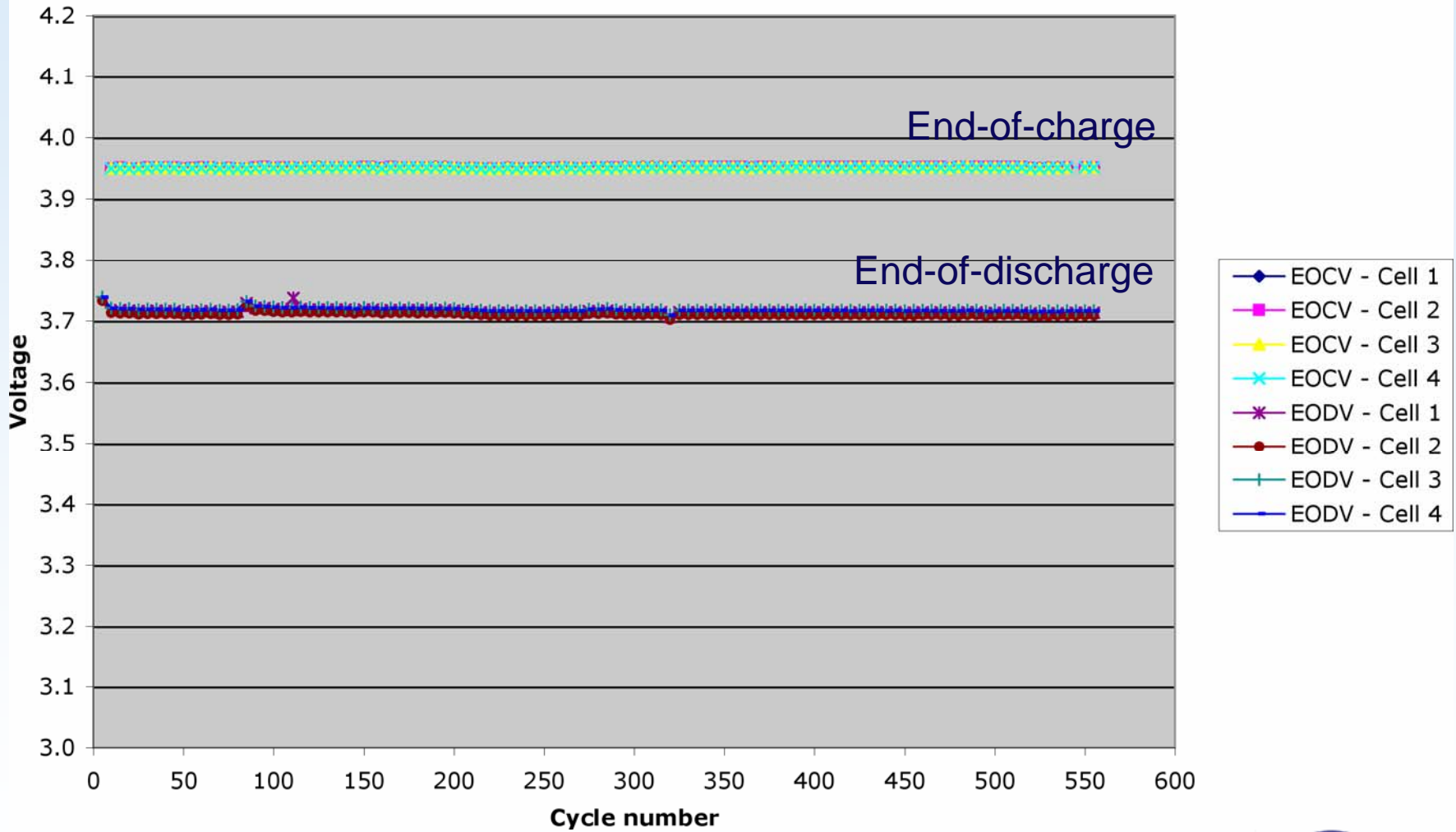




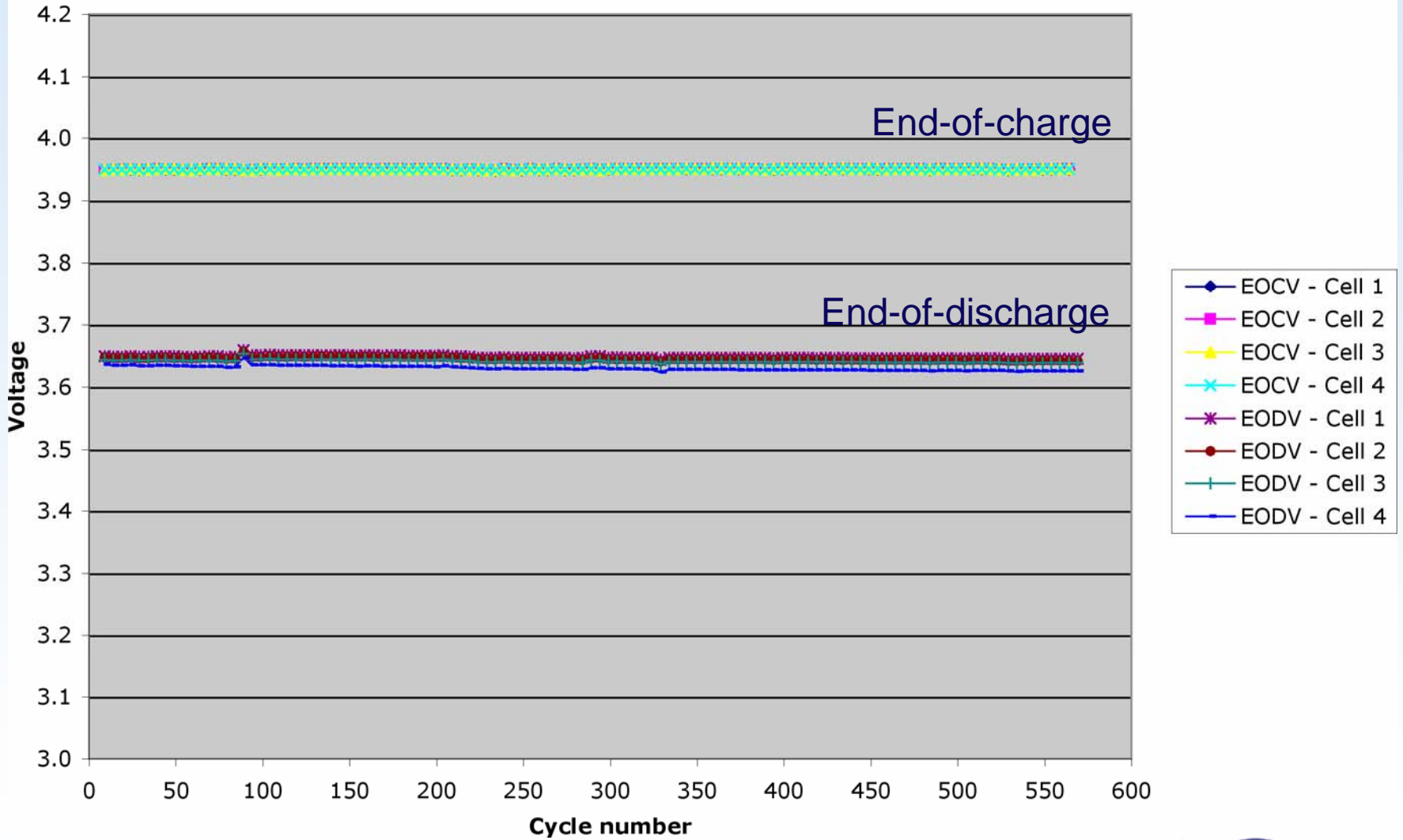
# Lithion cells 3.85 EOCV, 20°C, 30% DOD



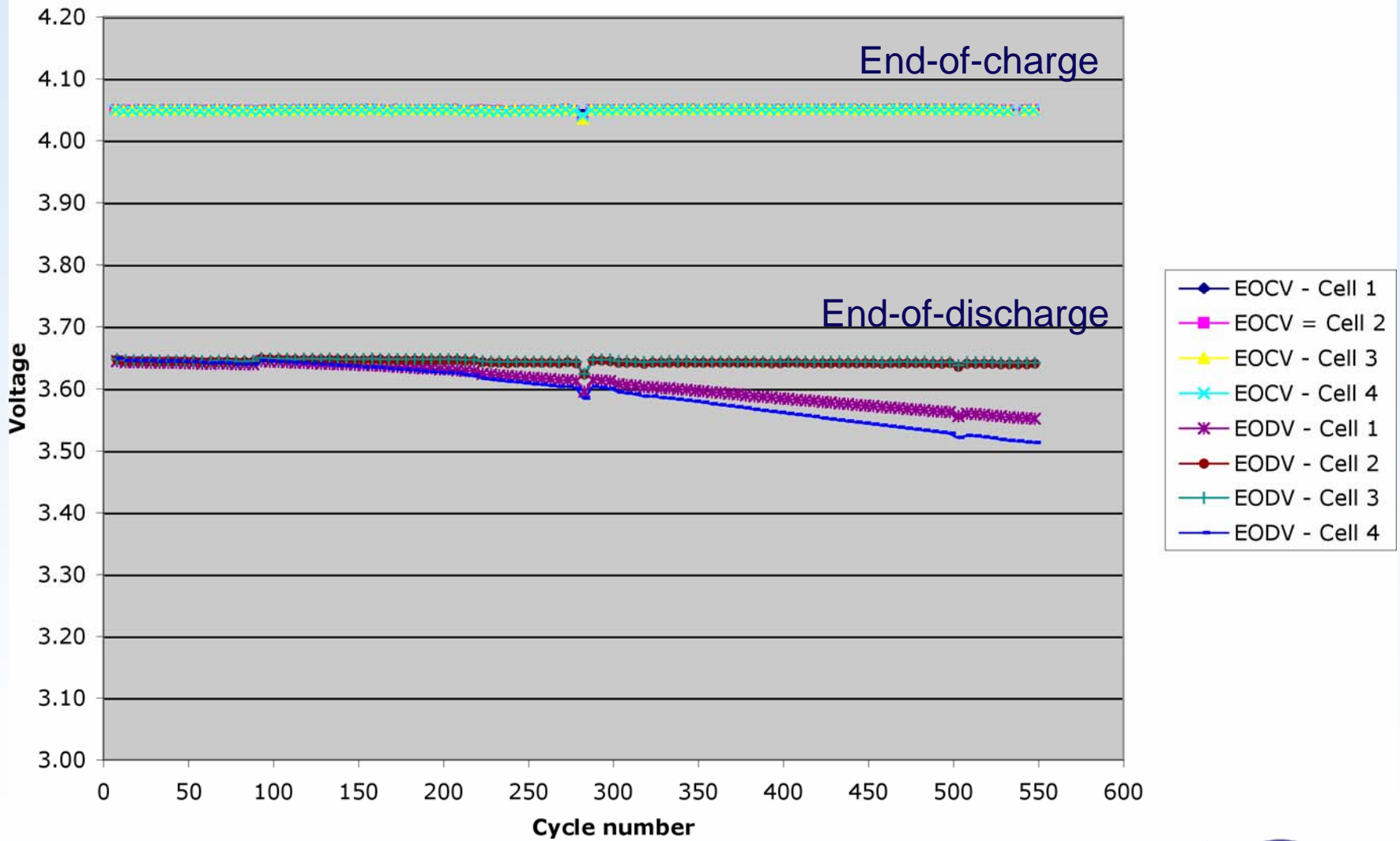
**Soft cells**  
**3.95 EOCV, 20°C, 20% DOD**



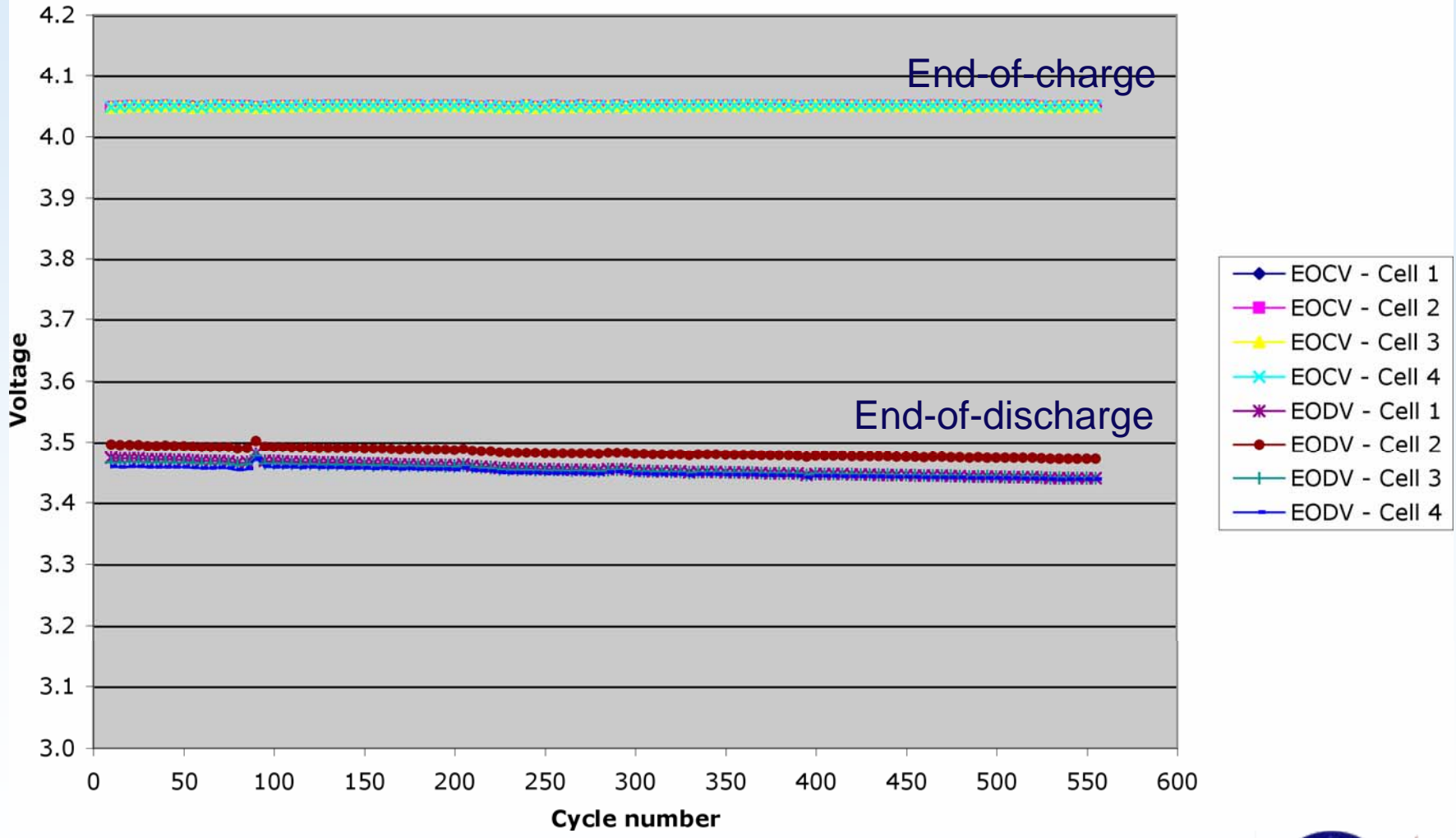
# Lithion cells 3.95 EOCV, 20°C, 20% DOD



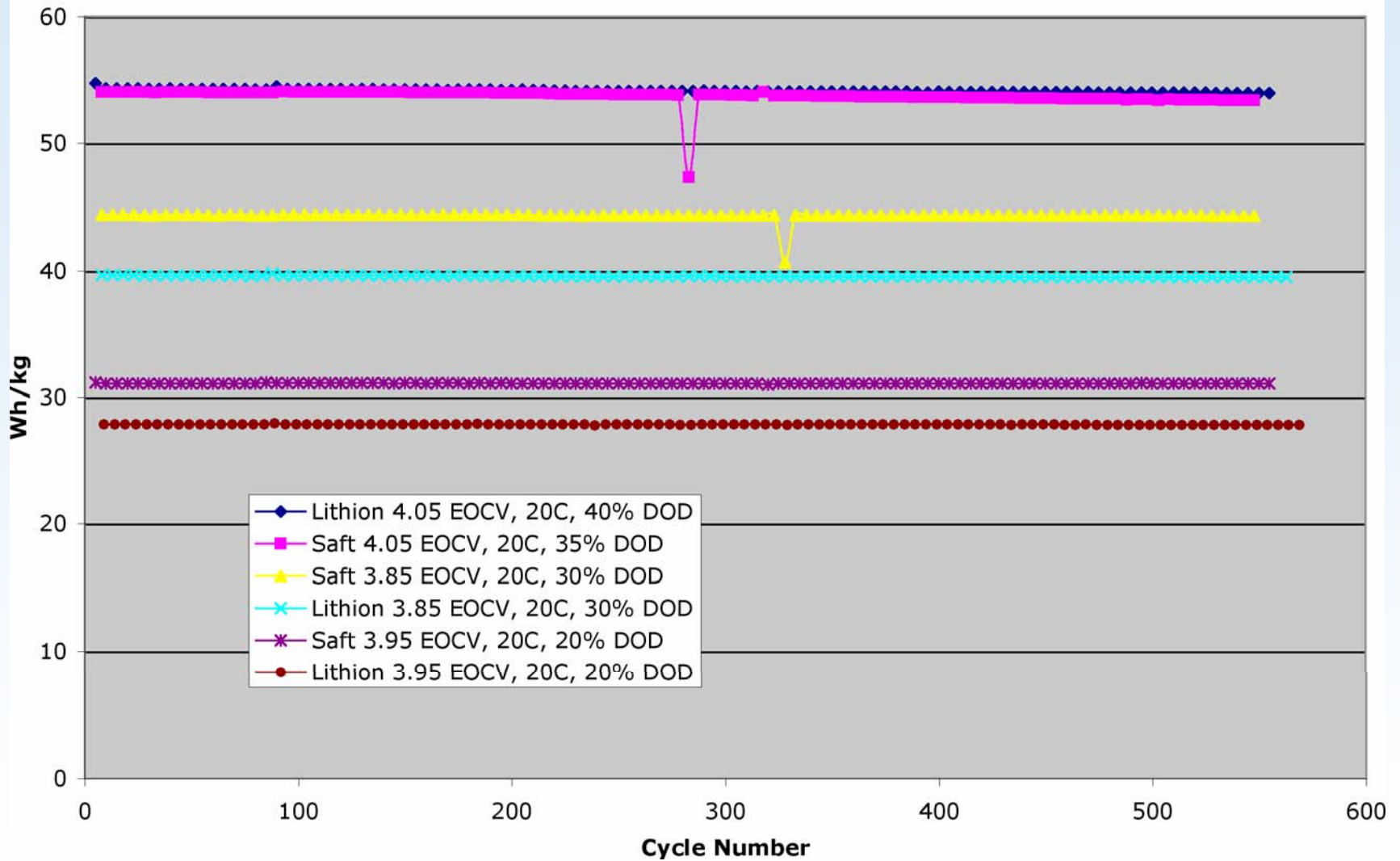
### Soft cells 4.05 EOCV, 20°C, 35% DOD



# Lithion cells 4.05 EOCV, 20°C, 40% DOD

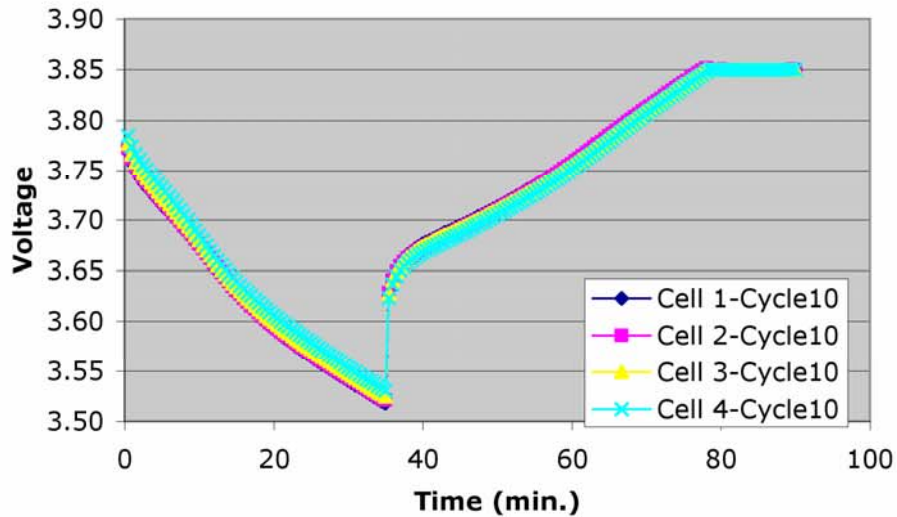


# Average Cell Energy Density Delivered

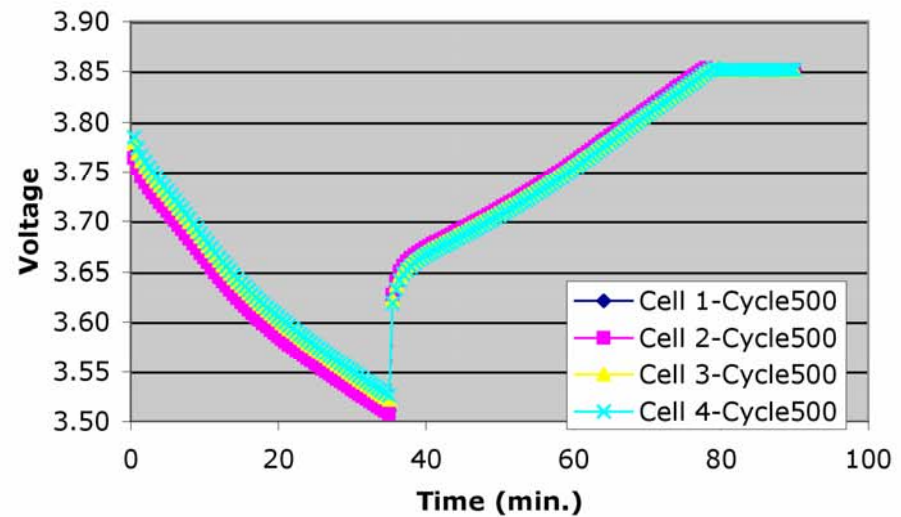


# Comparison of full cycle at 10 and 500 Cycles

**Soft cells**  
**3.95 EOCV, 20°C, 30% DOD**  
**Cycle 10**



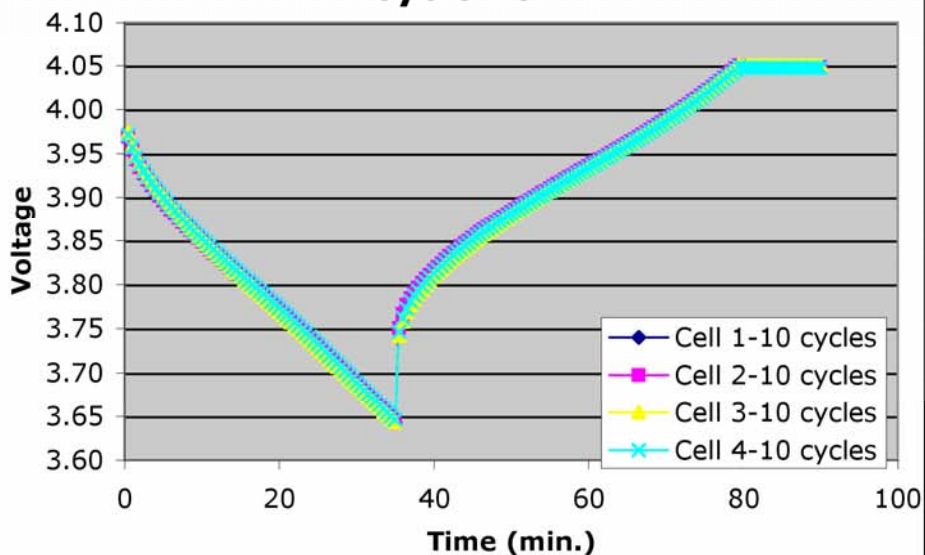
**Soft Cells**  
**3.95 EOCV, 20°C, 30% DOD**  
**Cycle 500**



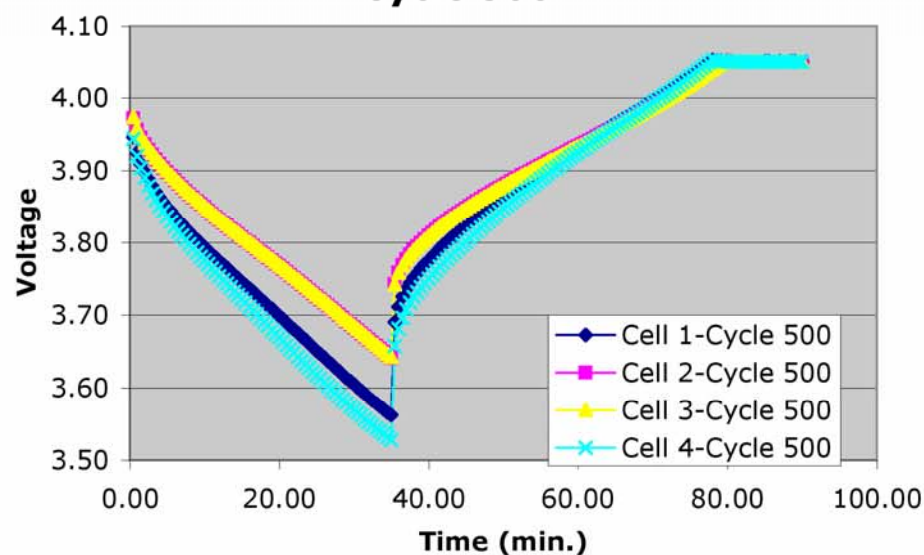


# Comparison of full cycle at 10 and 500 Cycles

**Soft cells**  
**4.05 EOCV, 20°C, 35% DOD**  
**Cycle 10**



**Soft cells**  
**4.05 EOCV, 20°C, 35% DOD**  
**Cycle 500**





# Lithium-Ion Verification Test Program

- Cell performance stable except for two cells at 4.05 EOCV, 20 degrees C, and 35% DOD
- Details on the charge control will be presented later in the workshop by Concha Reid of GRC and Evan Hand of NSWC/Crane



# Acknowledgements

- This work was funded by the NASA Aerospace Flight Battery Systems Program

