Long-Term Cycling and Analysis of 18650 Li-ion Cells Beyond 80% Capacity

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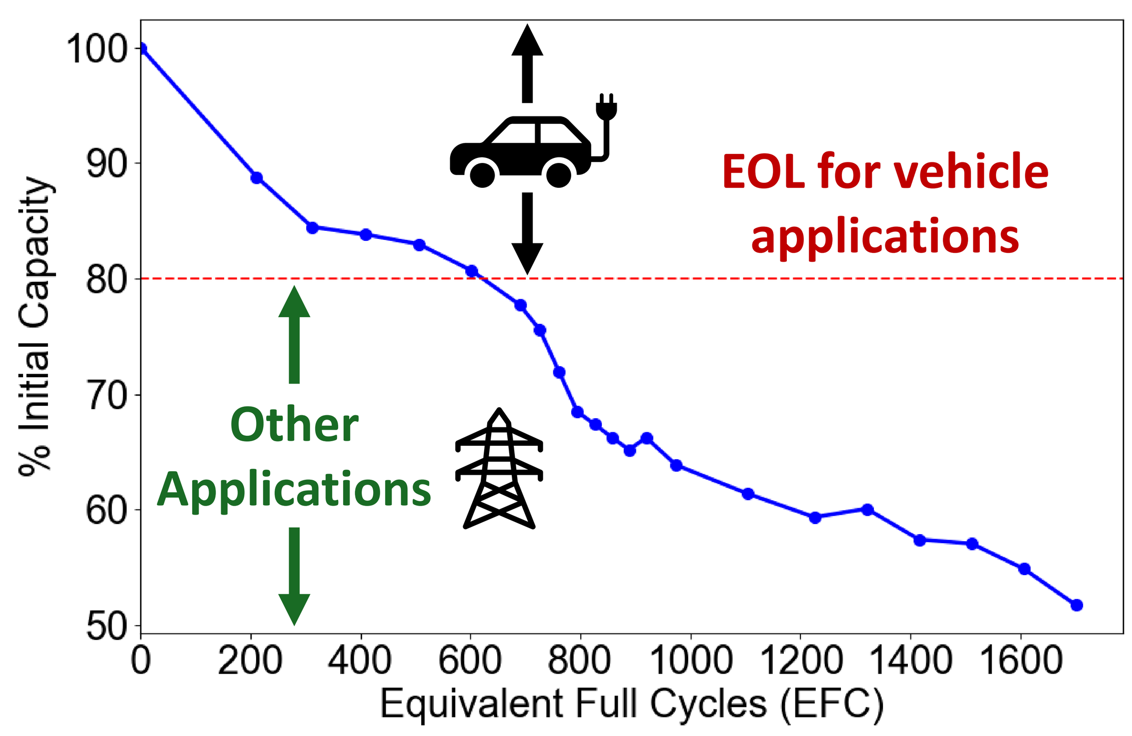
Introduction

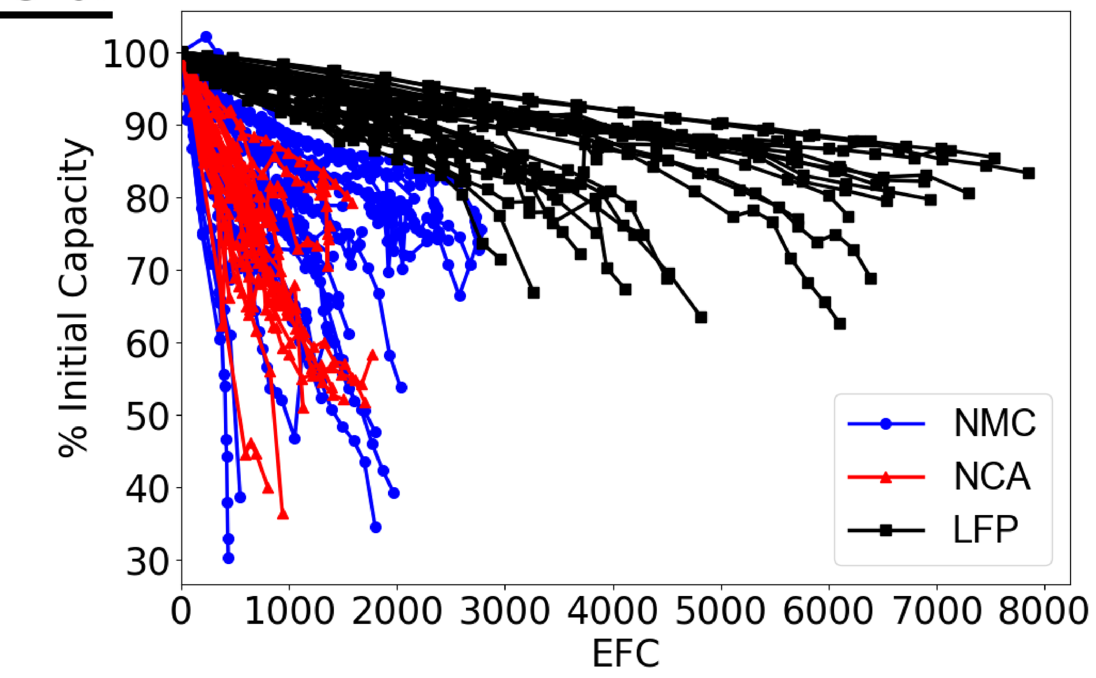


- Post 80% behavior is not well understood
- In 2017 we started the broadest public study of cycling of Li-ion batteries
- Our goal is to estimate point at which degradation behavior changes for each chemistry.

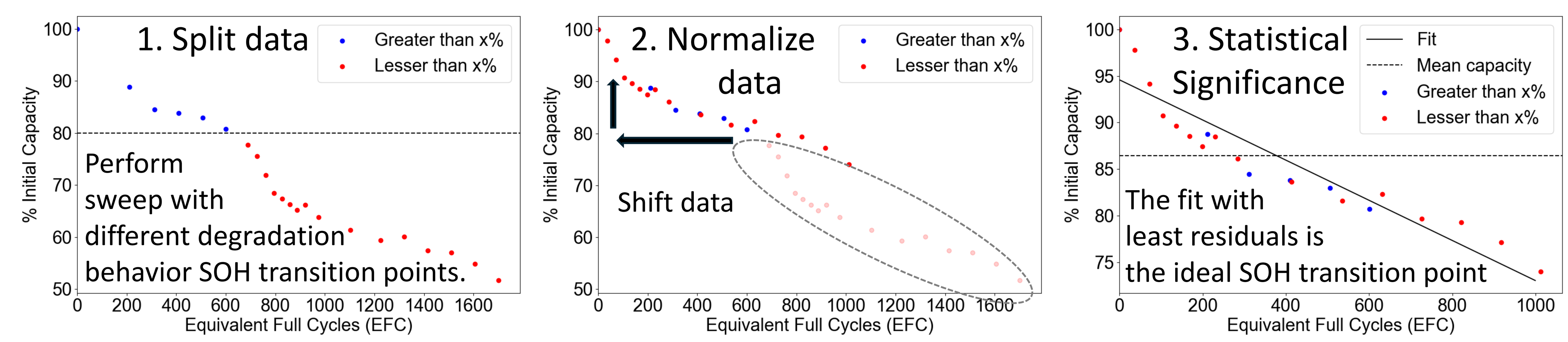
Method

Cycled 18650 format cells to 80% initial capacity[1] and now, to end of life of 40%

ANOVA is used to analyze the statistical significance of each parameter and estimate point at which degradation behavior changes.



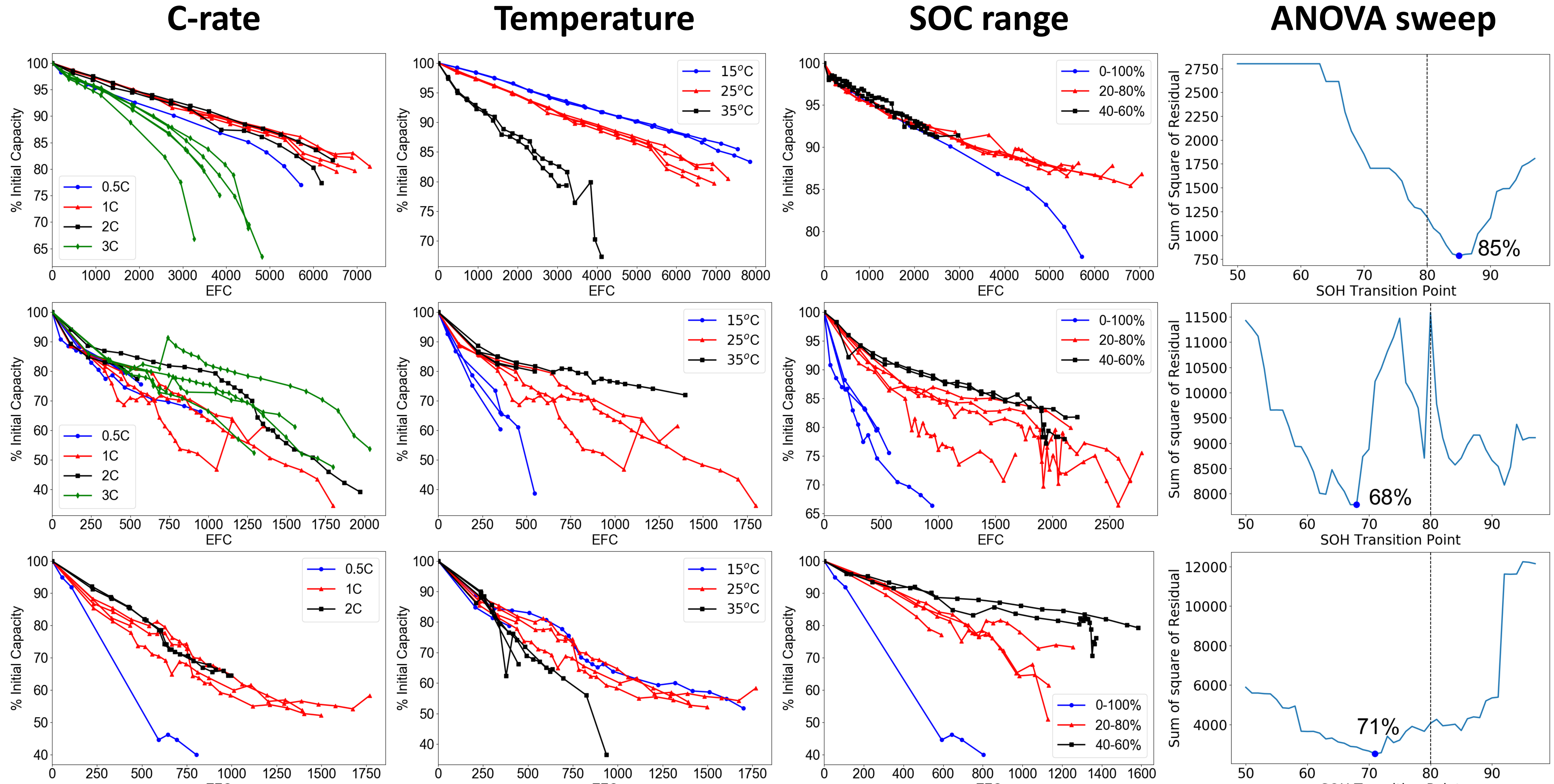
Analysis Parameters: State of Charge (SOC) range, Temperature, C-rate, Equivalent Full Cycles (EFC), State of Health (SOH) Transition point



Data Analysis

- Initial cycling in each conditions shows a linear degradation which changes to non-linear degradation post a certain point.
- Significance of each parameter changes based on chemistry, with SOC range showing the most consistent behavior. Larger SOC shows a greater degradation rate. C-rate and temperature show chemistry specific trends.

C-rate | **Temperature** | **SOC range** | **ANOVA sweep**



Chemistry	Significance of parameters
LFP (Lithium iron Phosphate)	1. Temperature 2. SOC 3. C-rate
NMC (Nickel Manganese Cobalt)	1. C-rate 2. Temperature 3. SOC
NCA (Nickel Cobalt Aluminum)	1. SOC 2. Temperature 3. C-rate

The **point of change in degradation behavior** varies based on **chemistry** and **use conditions** and is **not necessarily 80%.**

Battery lifetime can be increased by ensuring that parameters of high significance to the specific chemistry are set to optimum levels. For example, the lifetime of LFP can be increased by ensuring the battery is maintained at lower temperatures.

Conclusion

- Significance of parameters and degradation rates have a strong dependence on chemistry and use conditions.
- Knowing which parameters most effect each chemistry can help optimize usage and reduce degradation rates

Next Steps

- Continue cycling to end of life (40%).
- Refine ANOVA analysis.
- Quantify knee point occurrence.
- Investigate calendar aging trends.

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Reference:
1. Preger, Yuliya, et al. "Degradation of commercial lithium-ion cells as a function of chemistry and cycling conditions." *Journal of The Electrochemical Society* 167.12 (2020): 120532.

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