LiFETIME+ Interim Presentation

Enabling second-life battery production.

UNIVERSITY OF CAMBRIDGE

Centre for Global Equality

SENSOR CDT

UKRI Engineering and Physical Sciences Research Council

Our objectives have changed.

Recap on key terms

EIS - Electrochemical Impedance Spectroscopy

ICA - Incremental Capacity Analysis

ECM - Equivalent Circuit Model

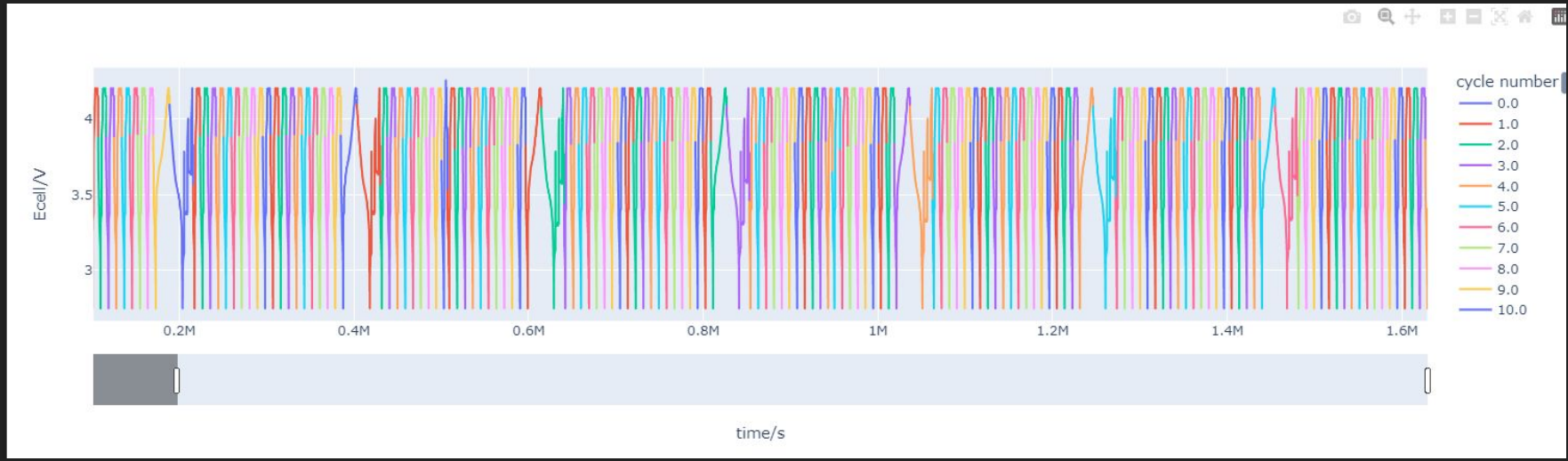
SOC - State of Charge

SOC - State of Health

Our new objectives

1. **Clean, process and visualise the EIS data.**
2. **Take an EIS route, finding an ECM and fitting it.**
3. **Investigate the trade-off between applicability and accuracy.**
4. **Report the feasibility of this approach.**

Capacity & Data Analysis



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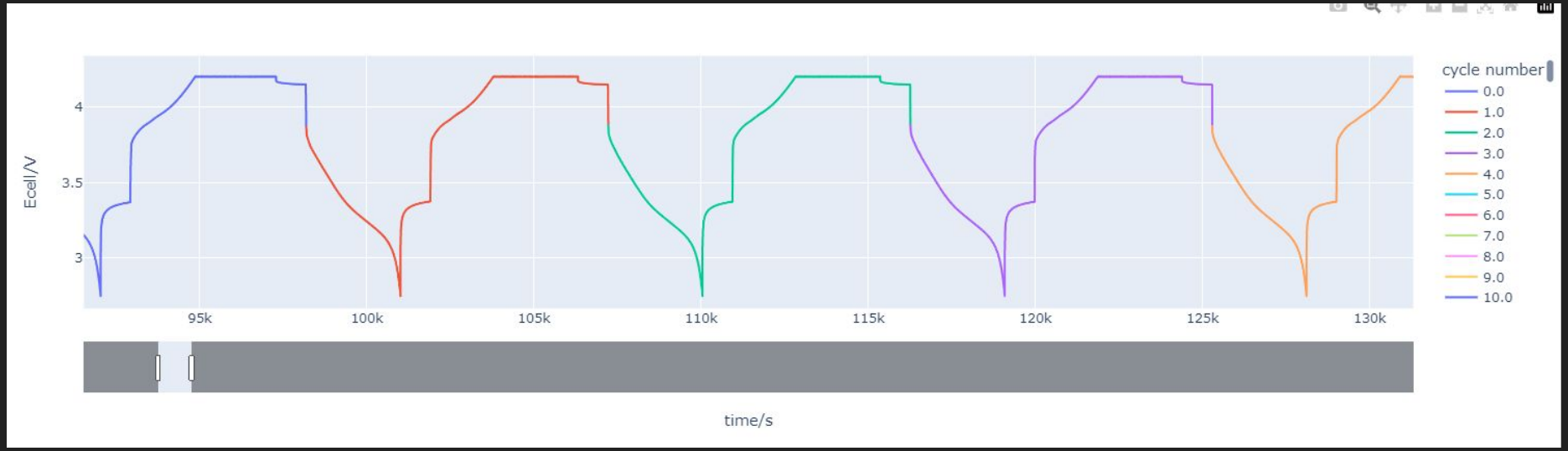

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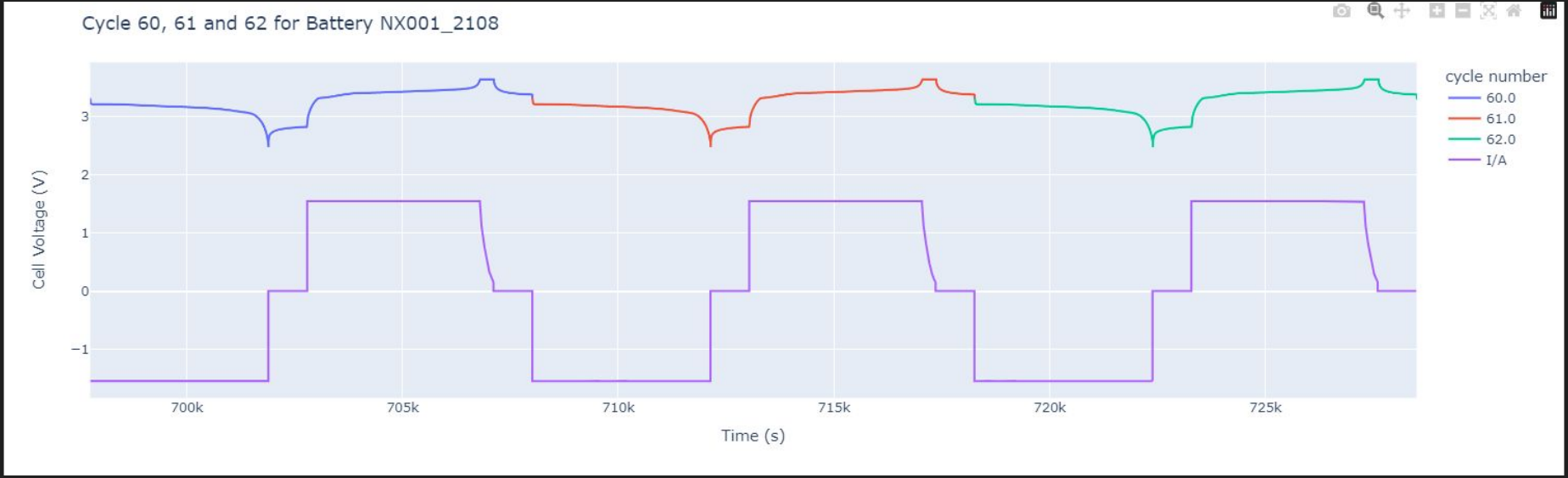

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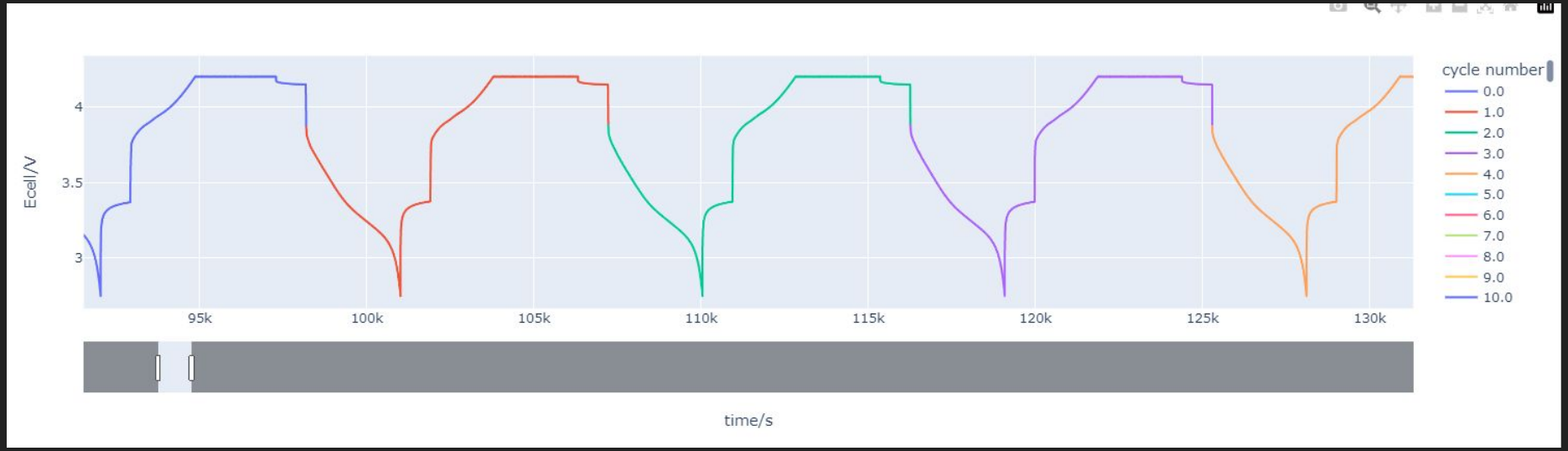

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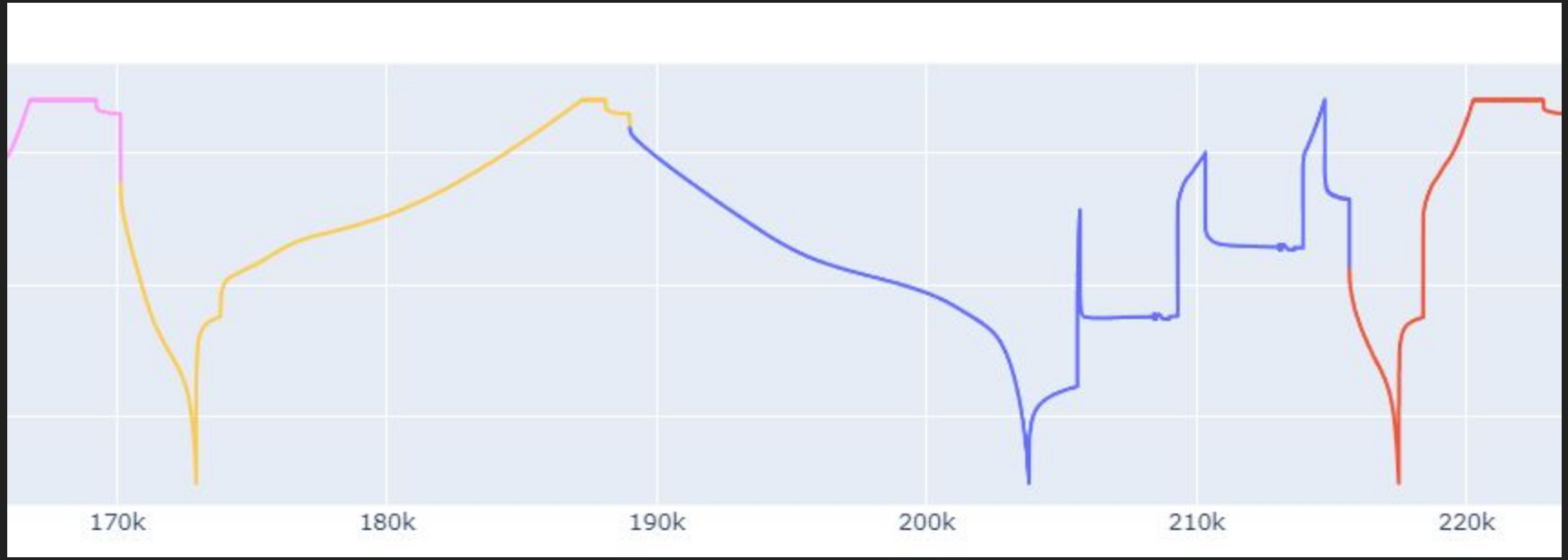

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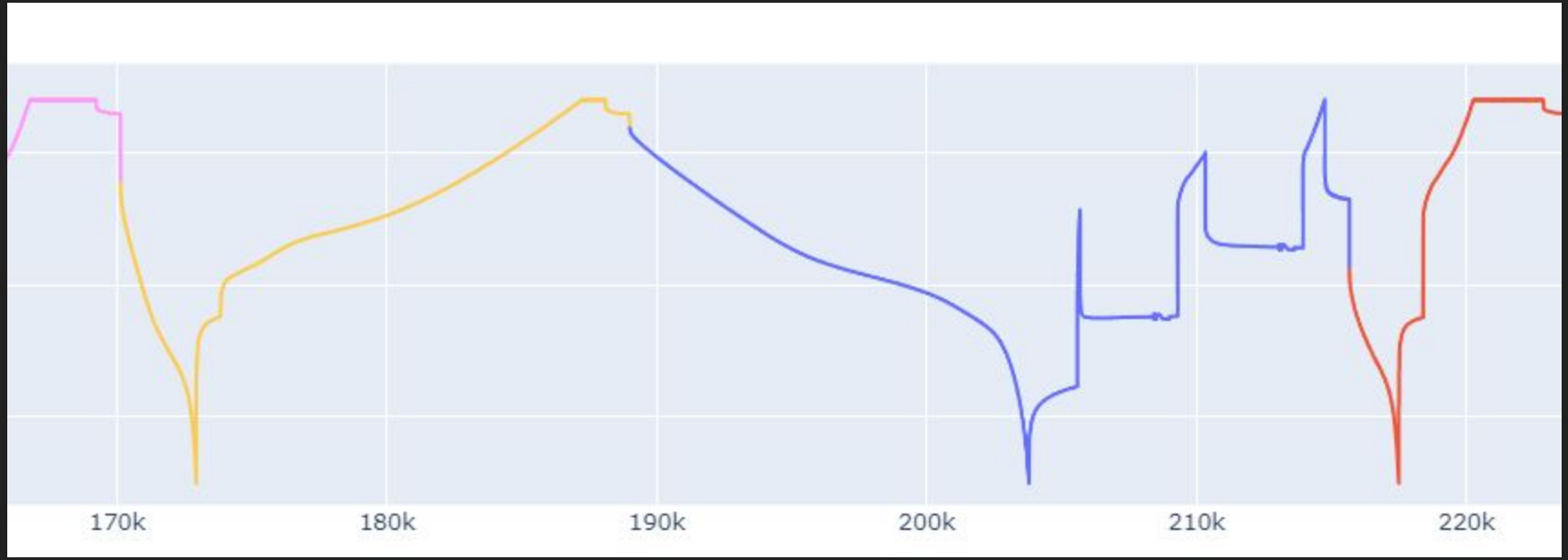

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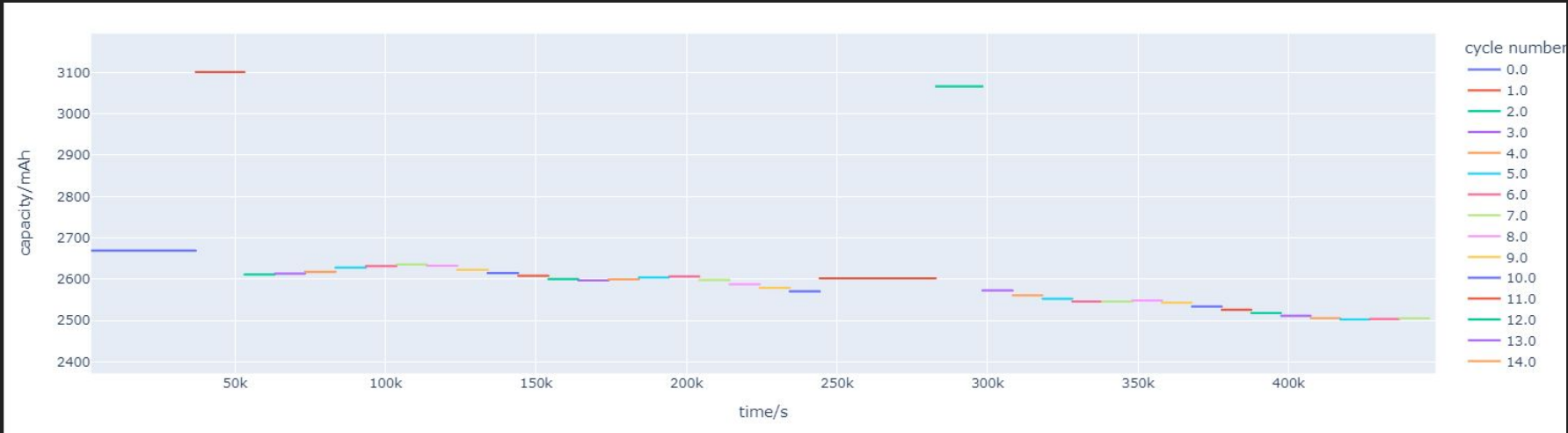
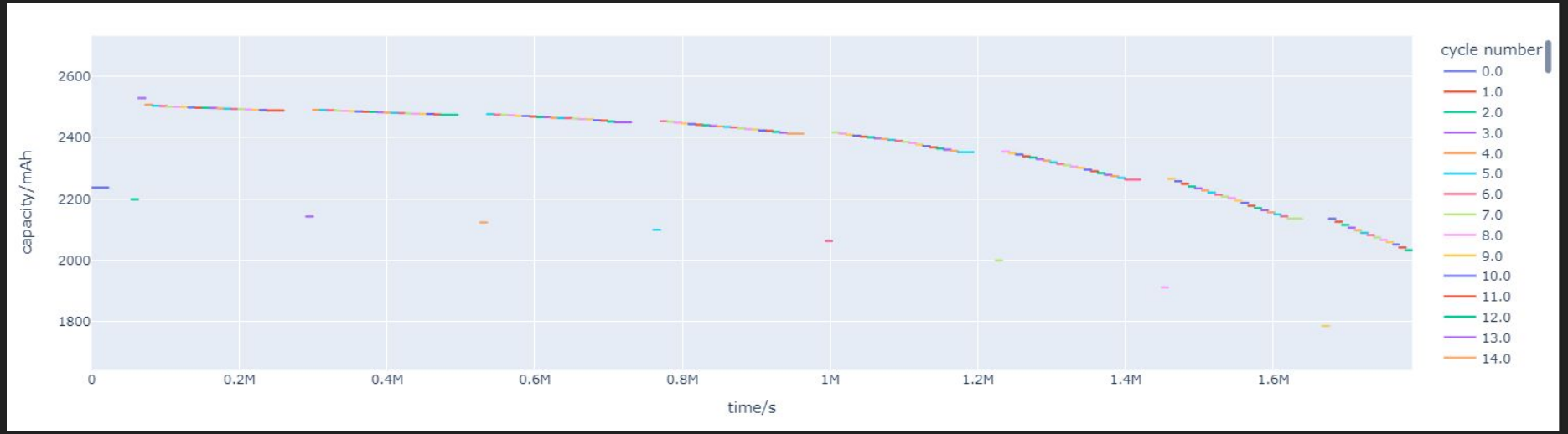


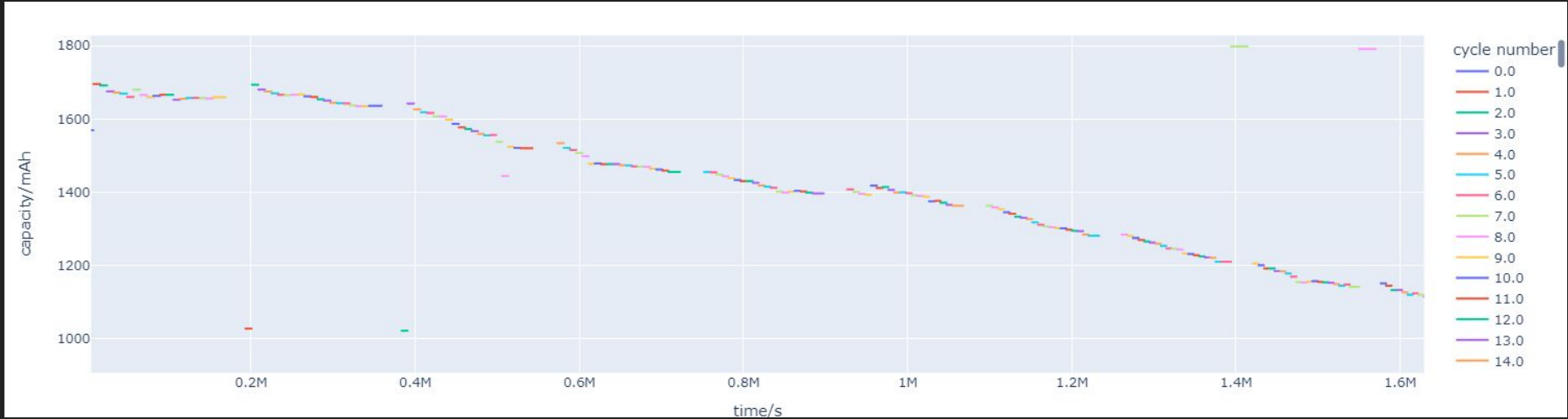
July

Capacity & Data Analysis



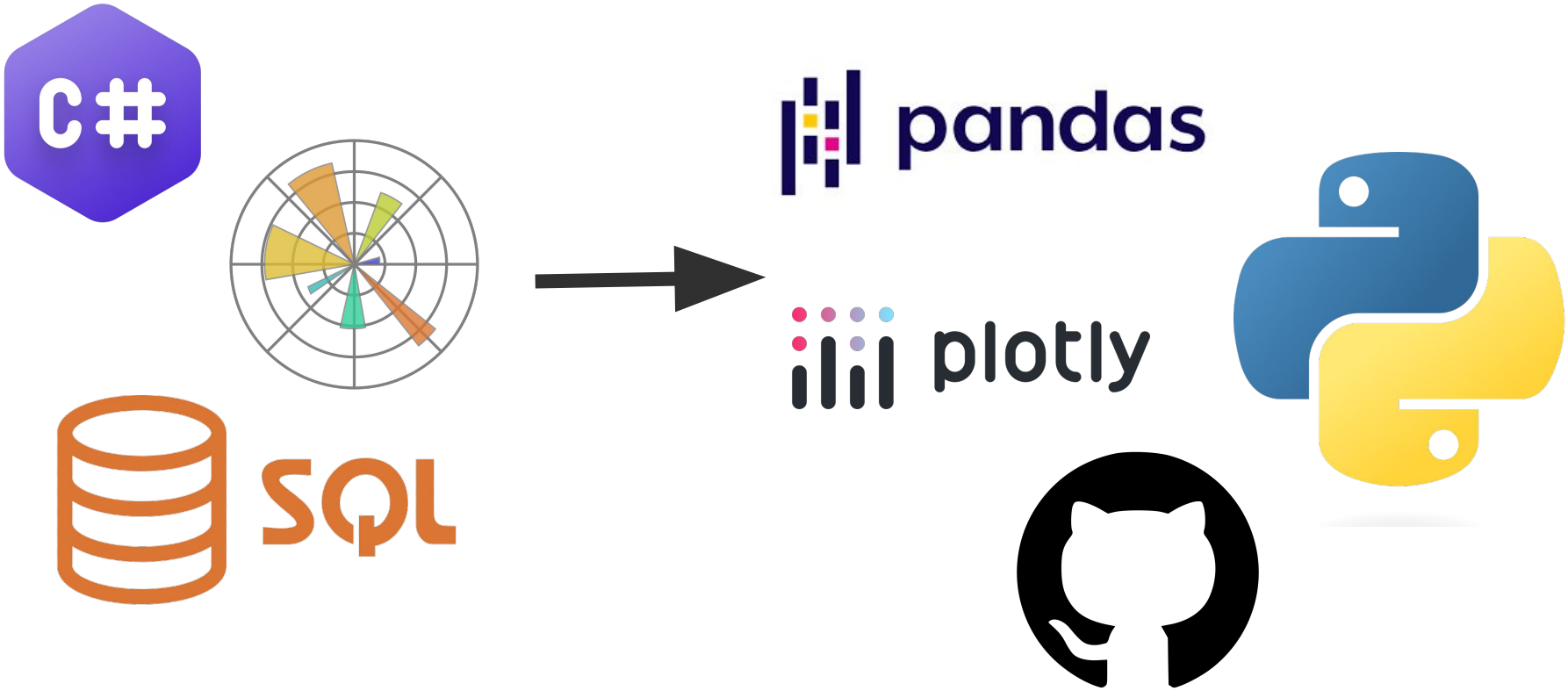
August

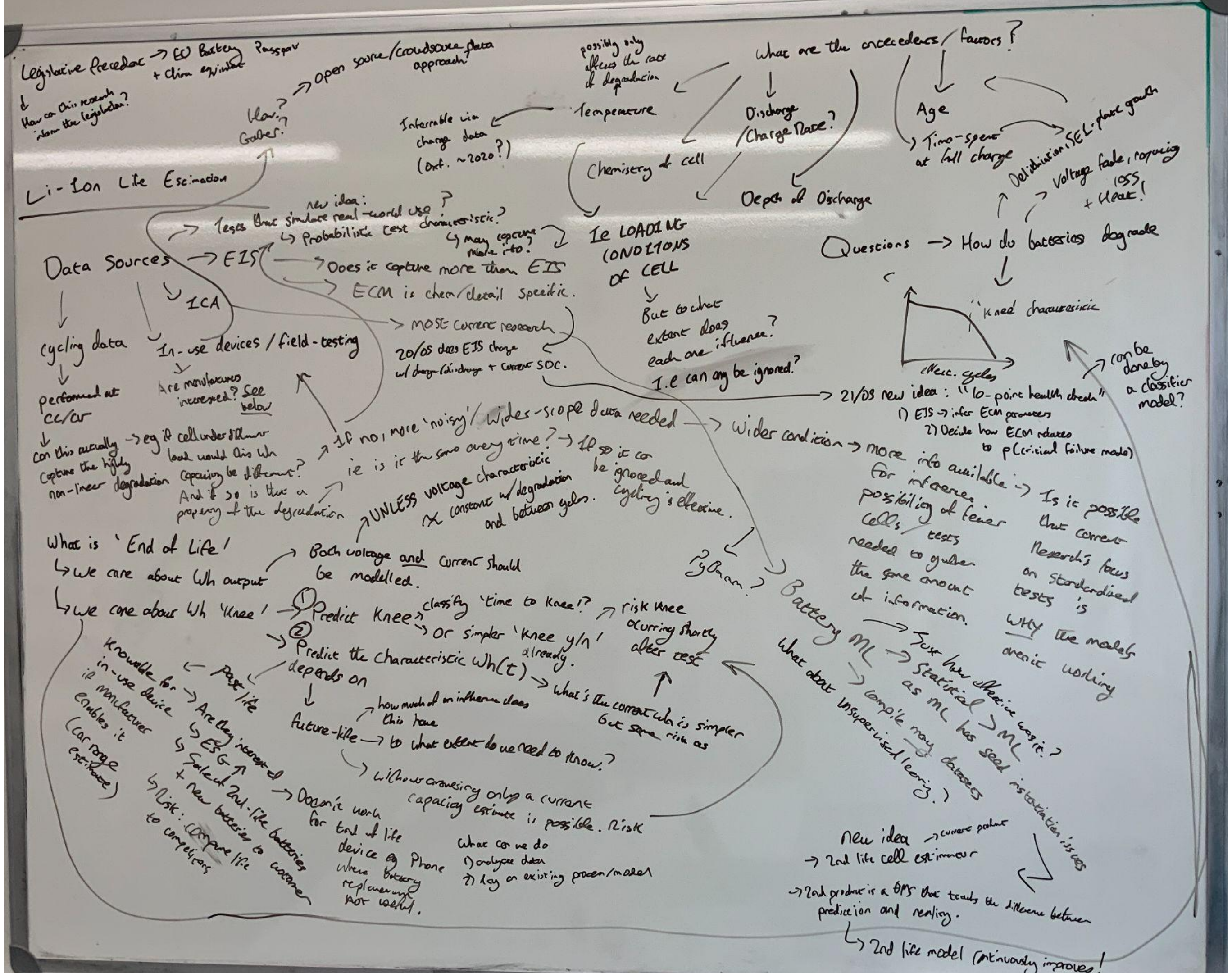
Capacity & Data Analysis



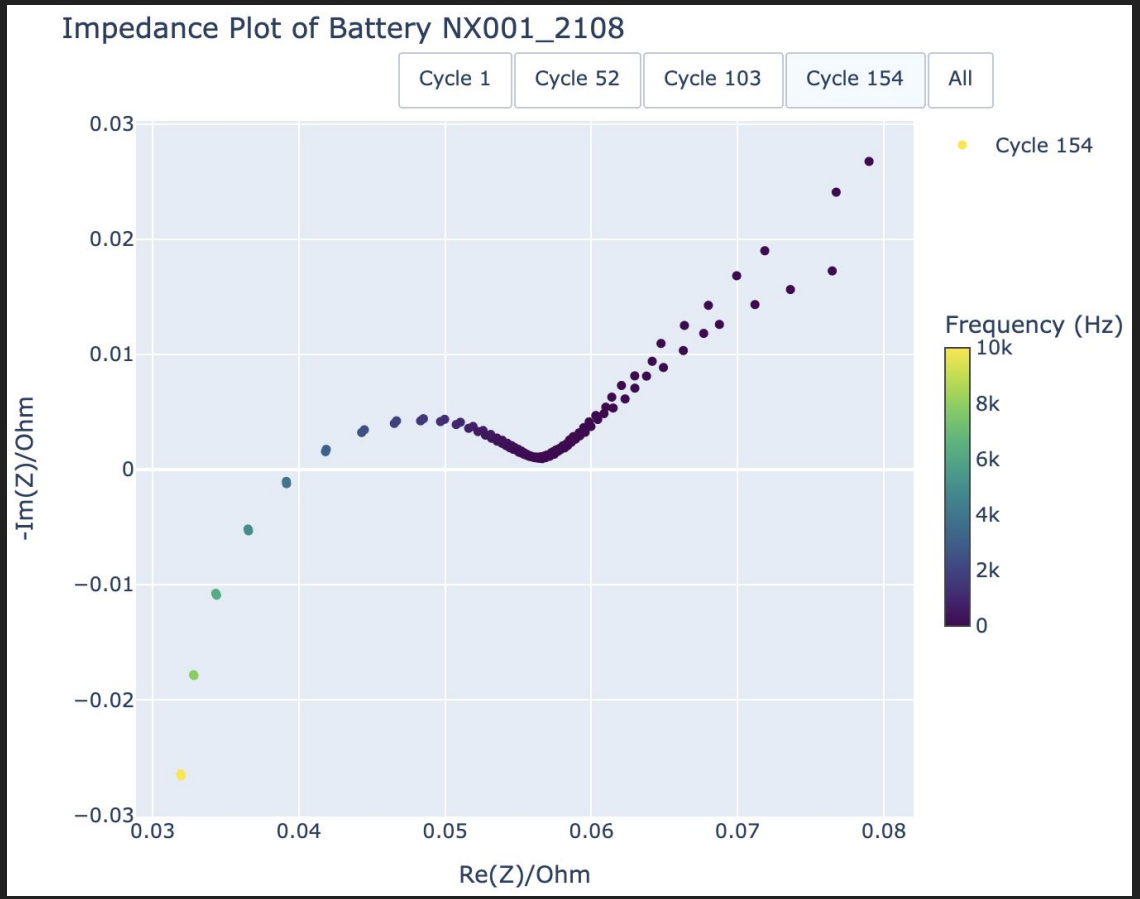
January

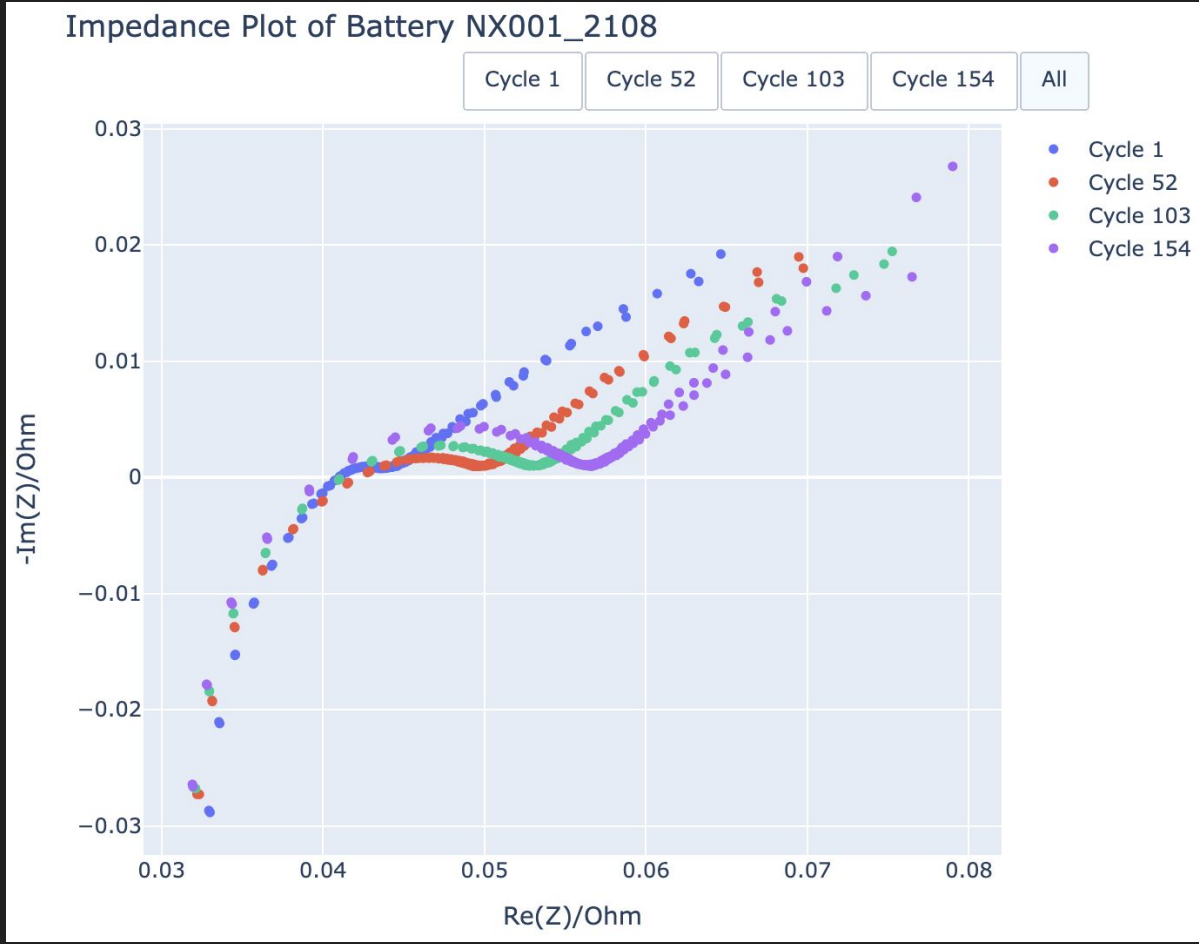
Personal and Technical Development - Joe




Legislative Precedent → EU Battery Passport + China equivalent
How can this research inform the legislation?
Li-Ion Life Estimation
How? Gather? → open source / crowdsource data approach
new idea: Tests that simulate real-world use?
↳ Probabilistic test characteristic?
↳ may capture more info?
Data Sources → EIS → Does it capture more than EIS
ECM is chem/detail specific.
ICA
→ MOST current research
20/05 does EIS change w/ charge/discharge + current SOC.
cycling data
performed at CC/CV
Can this actually capture the highly non-linear degradation
→ eg if cell under different load would this Wh capacity be different?
And if so is that a property of the degradation
In-use devices / field-testing
Are manufacturers interested? See below
If no, more 'noisy' / wider-scope data needed → wider condition → more info available for inference.
ie is it the same every time? → If so it can be ignored and cycling's effective.
UNLESS voltage characteristic ∝ constant w/ degradation and between cycles.
possibly only affects the rate of degradation
What are the antecedents / factors?
Temperature
Inferrable via charge data (est. ~2020?)
Chemistry of cell
Discharge / Charge Rate?
Depth of Discharge
Age
↳ Time spent at full charge
Ie LOADING CONDITIONS OF CELL
↳ But to what extent does each one influence?
I.e can any be ignored?
Delithiation SEI plate growth
Voltage fade, capacity loss, + Heat!
Questions → How do batteries degrade
knee characteristic
elec. cycles
21/05 new idea: "10-point health check"
1) EIS → infer ECM parameters
2) Decide how ECM relates to p(critical failure mode)
can be done by a classifier model?
possibility of fewer cells / tests needed to gather the same amount of information.
Is it possible that current Research's focus on standardised tests is WHY the models aren't working
What is 'End of Life'
↳ We care about Wh output
↳ We care about Wh 'knee'
→ Both voltage and current should be modelled.
① Predict knee? classify 'time to knee'? → Or simpler 'knee y/n' already
→ risk knee occurring shortly after test
② Predict the characteristic Wh(t) depends on
→ What's the current Wh is simpler but same risk as
Past life
Future-life → to what extent do we need to know?
how much of an influence does this have
without traversing only a current capacity estimate is possible. Risk
Knowable for in-use device if manufacturer enables it (car range estimate)
Are they interested
↳ ESG
+ Select 2nd-life batteries + new batteries to customer
↳ Risk: Compare life to competitors
→ Doesn't work for End of life device eg Phone where battery replacement not useful.
What can we do
1) analyse data
2) rely on existing process/model
Jian?
Battery ML
→ Just how effective was it?
→ Statistical → ML as ML has seed instantiation issues
↳ compile many datasets
What about unsupervised learning?)
New idea → current product
→ 2nd life cell estimator
→ 2nd product is a BMS that tracks the difference between prediction and reality.
↳ 2nd life model continuously improves!

ECM and EIS


Impedance Plot of Battery NX001_2108
Cycle 1
Cycle 52
Cycle 103
Cycle 154
All
Cycle 154
Frequency (Hz)
10k
8k
6k
4k
2k
0
-Im(Z)/Ohm
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
0.03
0.04
0.05
0.06
0.07
0.08
Re(Z)/Ohm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All
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−0.01
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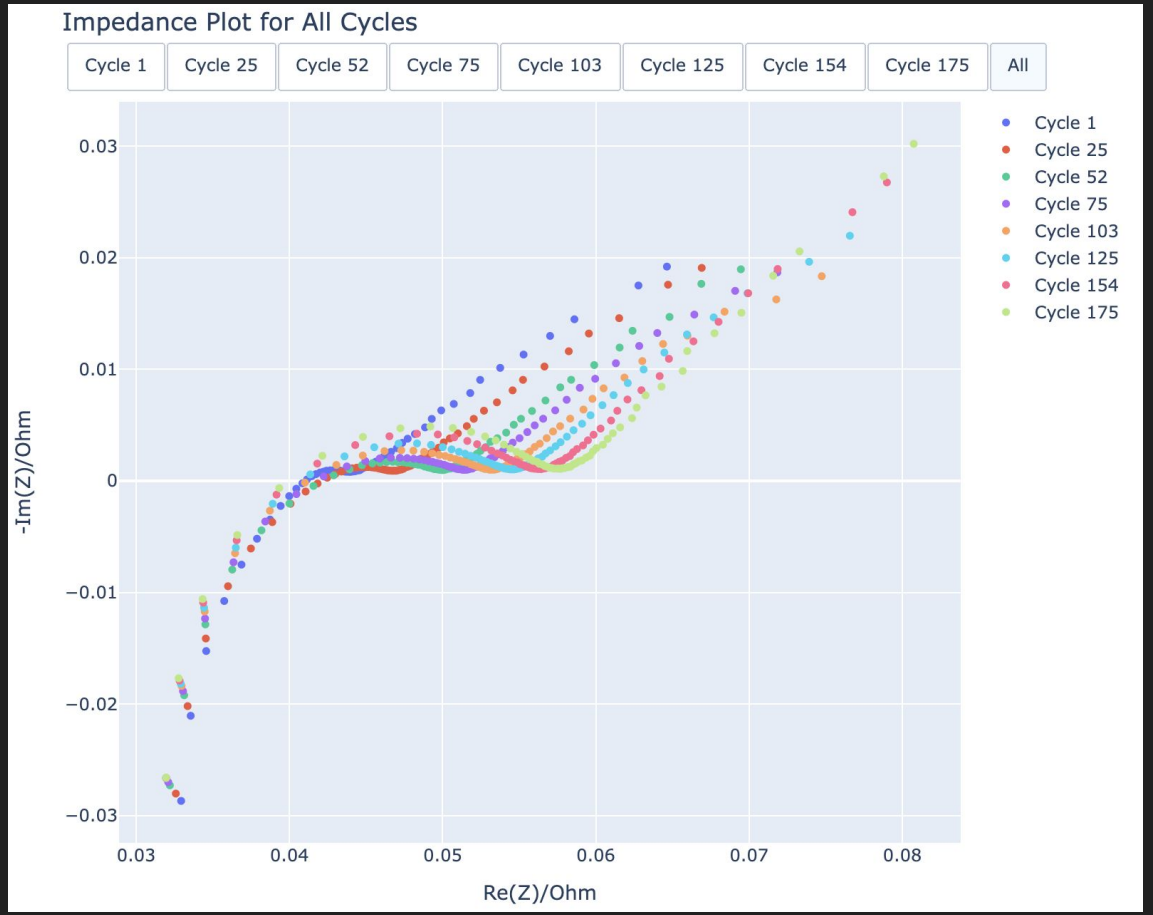
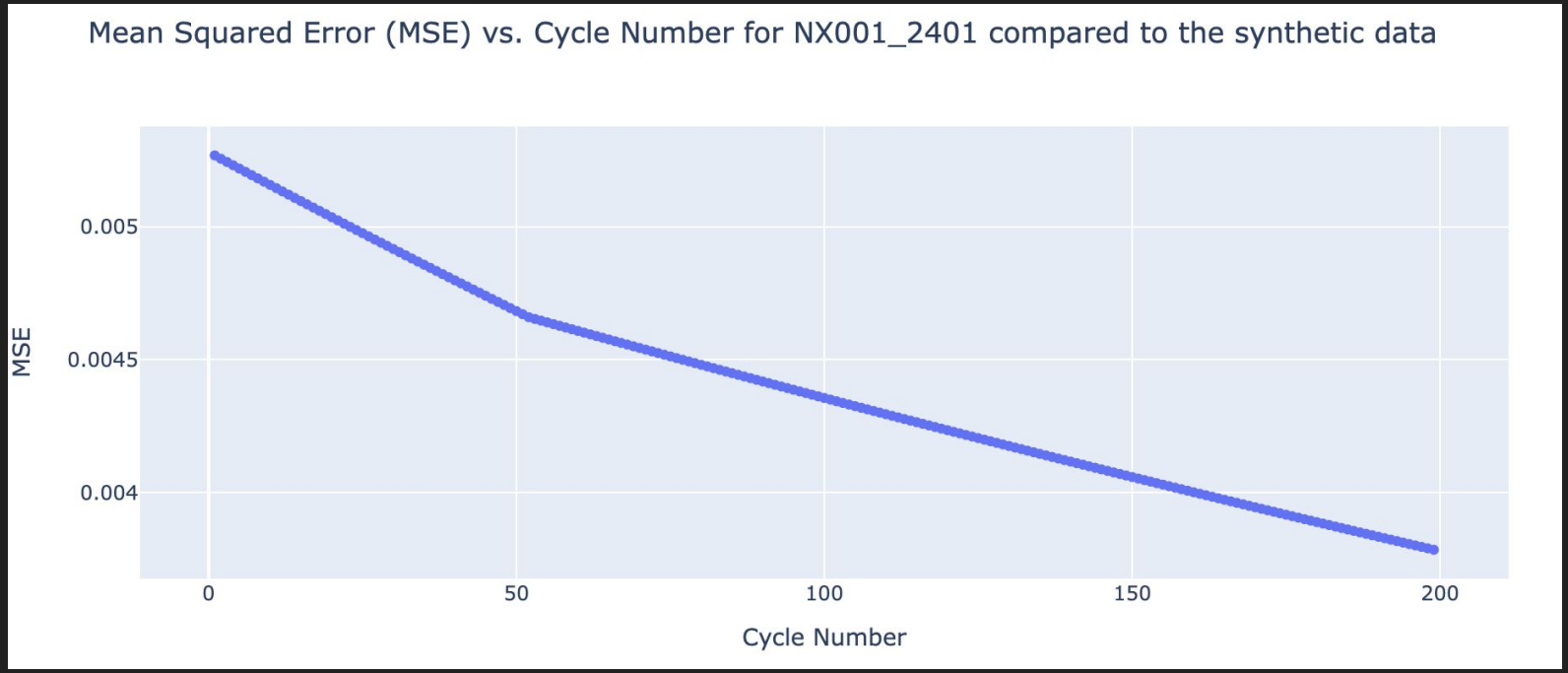
Synthetic data

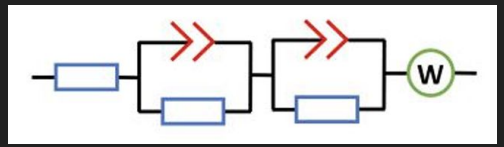


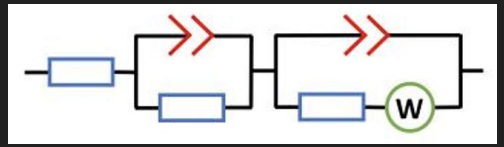
Batteries degrade, even when not used…

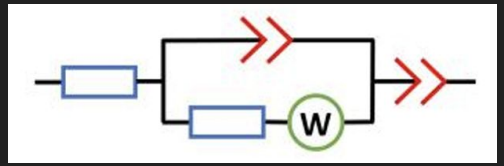
Two tests, done in August 2023 and January 2024

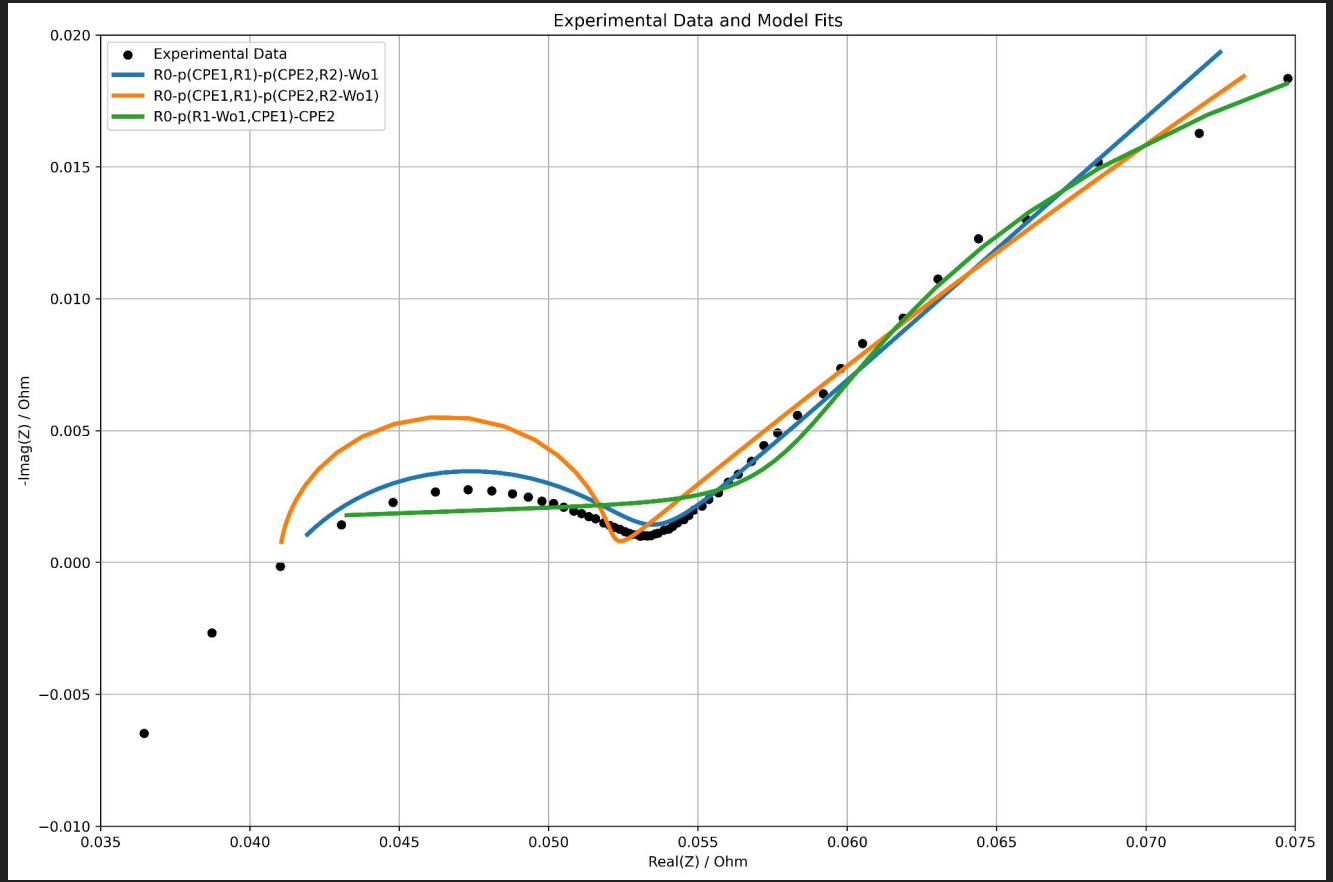


Fitting an ECM

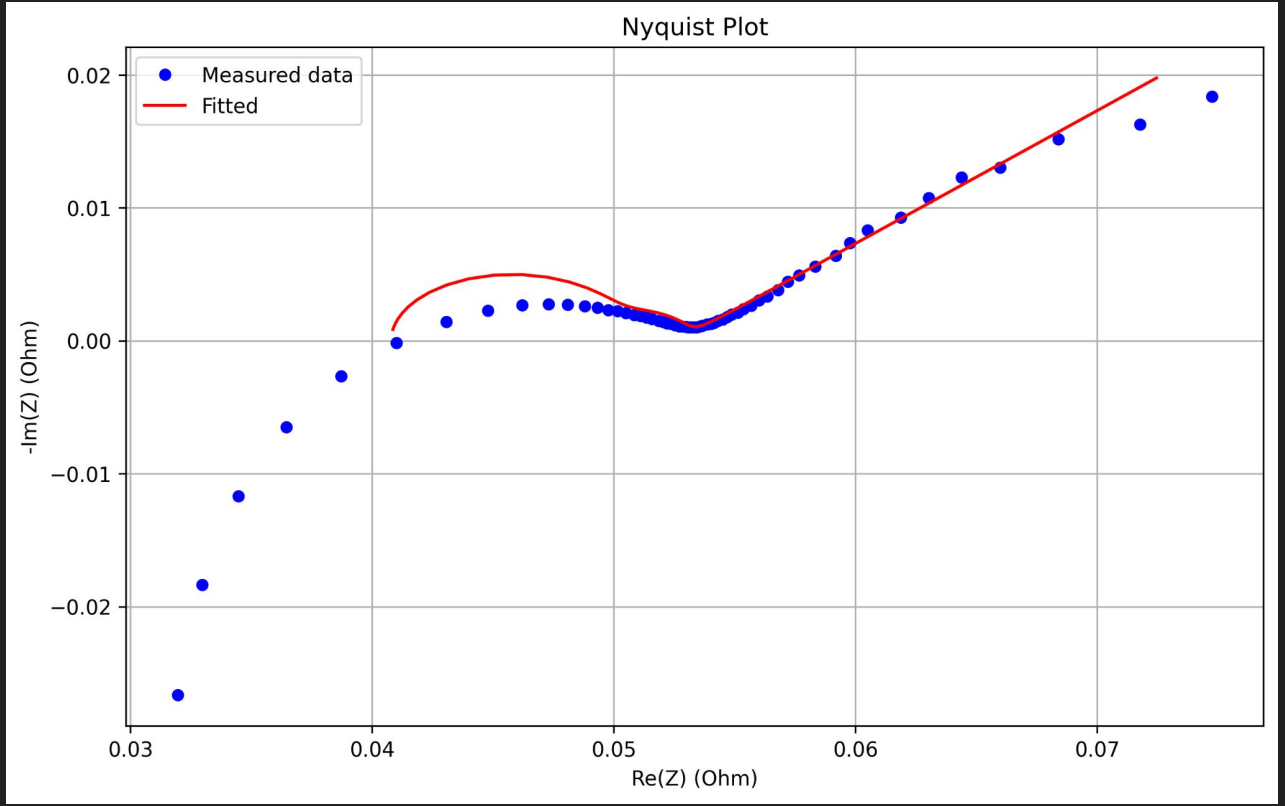




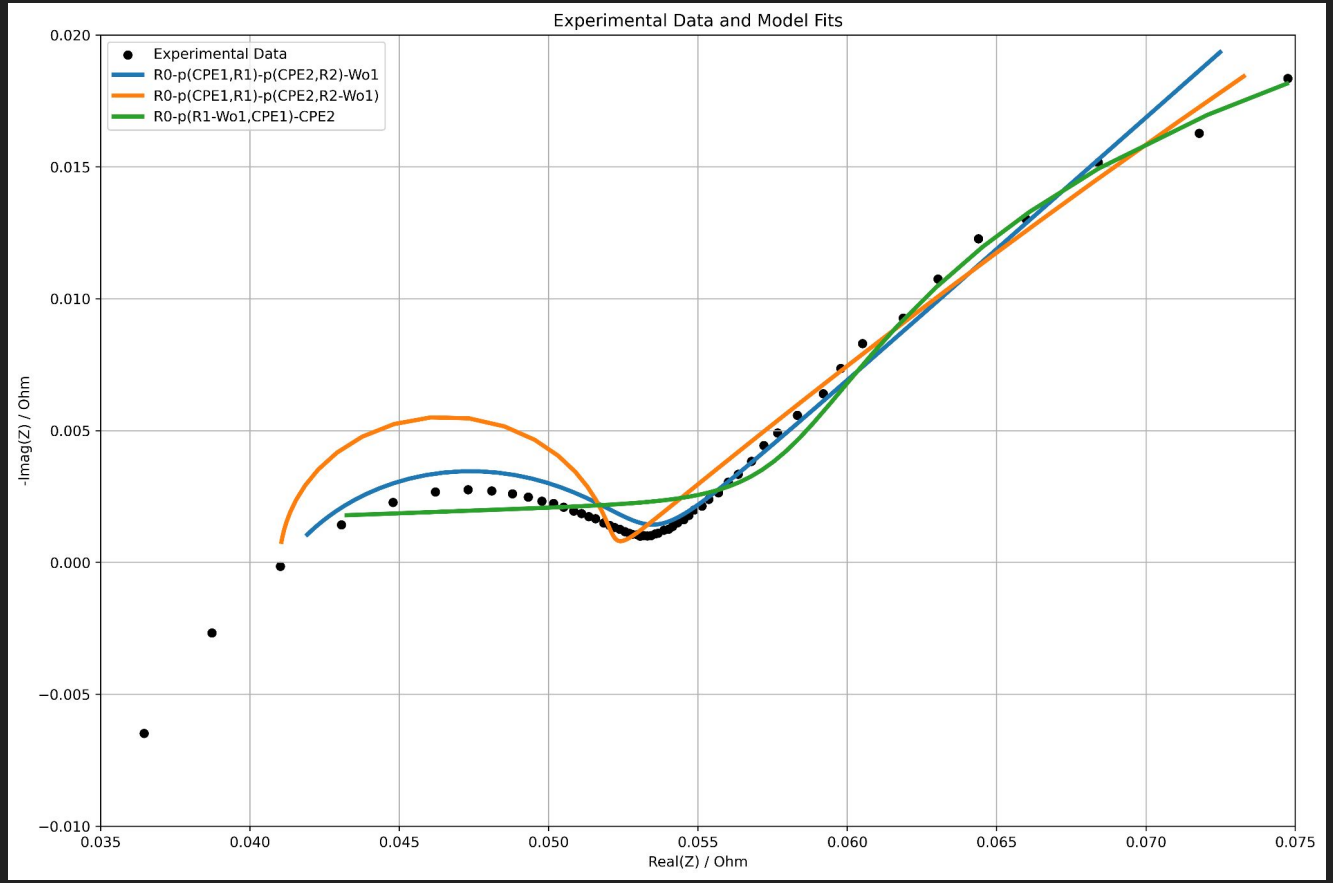




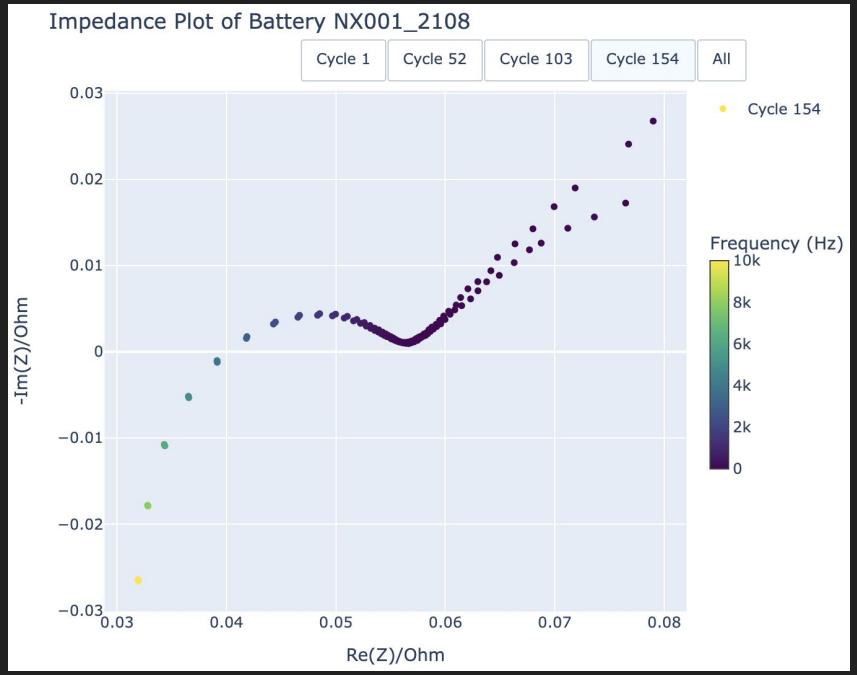
Issues with mean square error (MSE) weighting

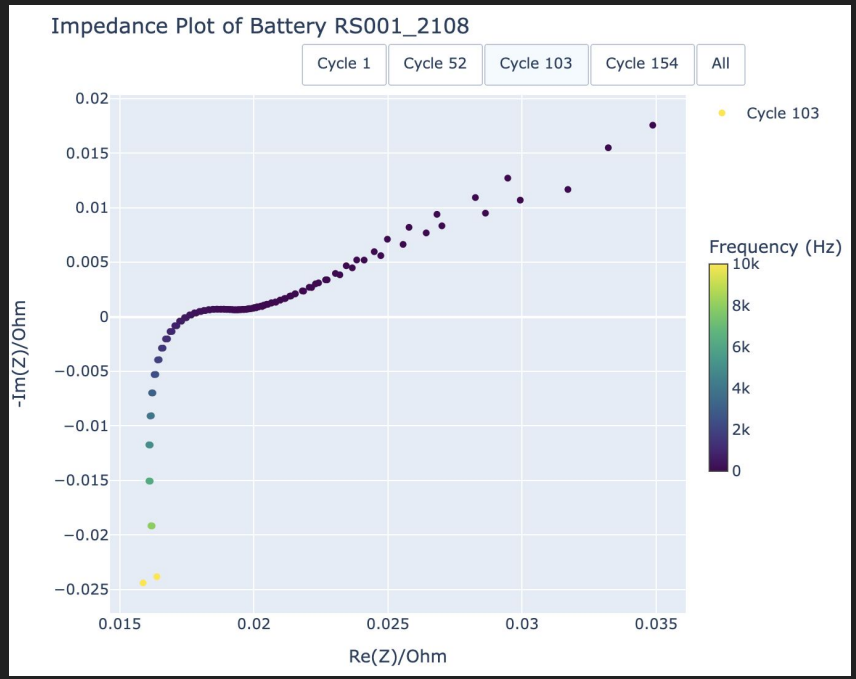


Is it feasible?

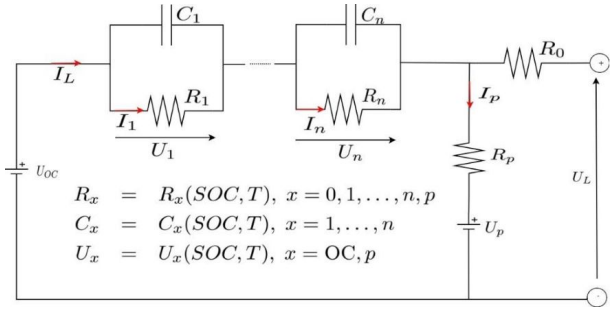

Experimental Data and Model Fits
Experimental Data
R0-p(CPE1,R1)-p(CPE2,R2)-Wo1
R0-p(CPE1,R1)-p(CPE2,R2-Wo1)
R0-p(R1-Wo1,CPE1)-CPE2
-Imag(Z) / Ohm
Real(Z) / Ohm
0.020
0.015
0.010
0.005
0.000
−0.005
−0.010
0.035
0.040
0.045
0.050
0.055
0.060
0.065
0.070
0.075

Spectra differ for different battery types





Personal and Technical Development - Amy



Problems Encountered:

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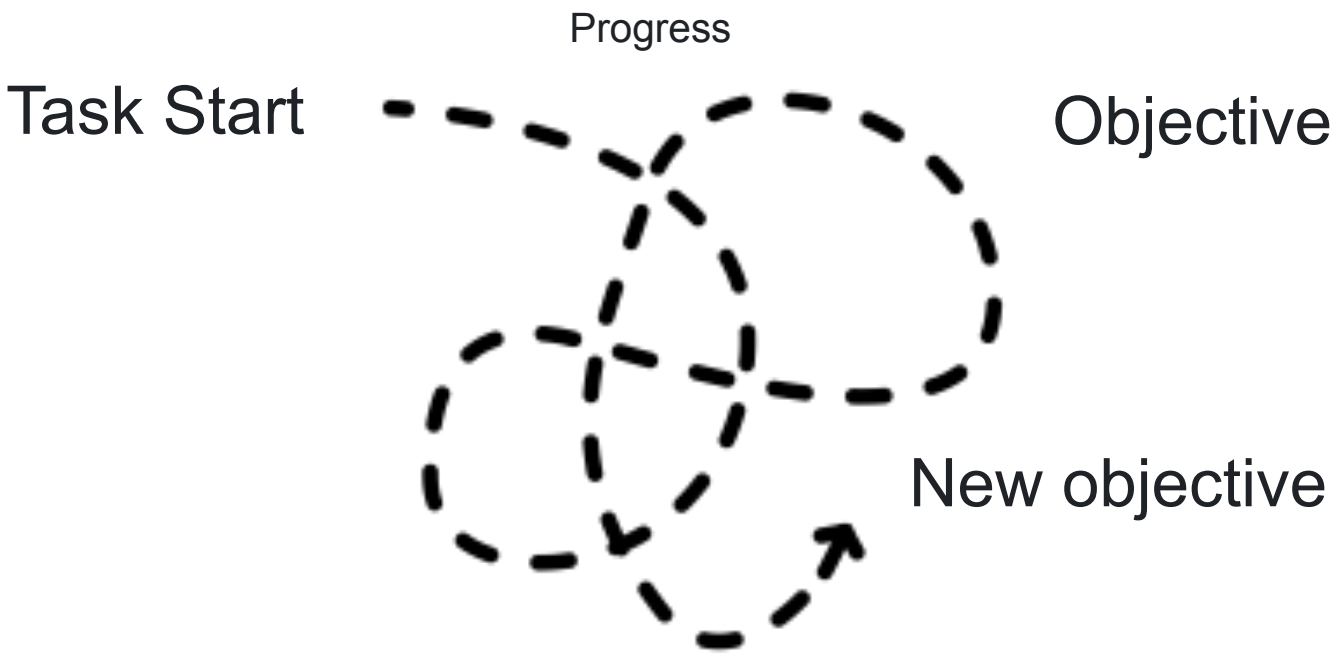

Documentation is everything.

Key Issues Faced

- **We still don’t have access to LiFETIME’s GitHub**
- **Difficulty with data due to general lack of documentation of the data**
- **The LiFETIME team are pretty busy**

Plan

1. Clean, process and visualise the EIS data
2. Document the data
3. Choose an ECM, using literature and our EIS data, building on current progress
4. Get a better picture of how each ECM component links to a physical aspect of the cell
5. Fit the parameters of the ECM for a single SOC, cycle number and battery type
6. Quantitatively report whether the ECM is valid for the other battery types
7. Investigate how the ECM parameters change with SOC and cycle number

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Project Plan

Fri 10th

Project Start

Literature review.

Wednesday 15th

First meeting with LiFETIME

Obtained necessary data and discussed initial research.

Thursday 16th

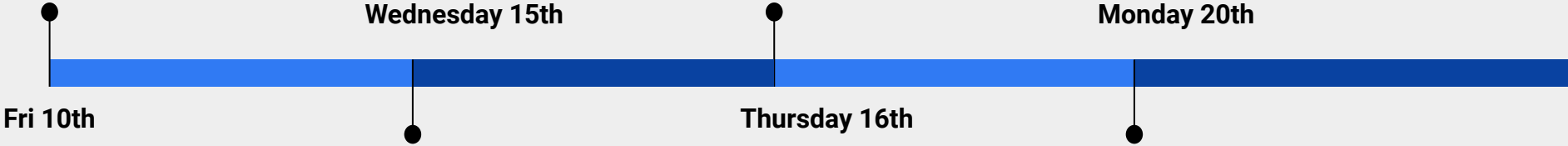
Proposal Presentation

Present initial findings from literature review and suggested avenues forward. Received feedback on feasibility of our plans.

Monday 20th

2nd meeting with LiFETIME

Gave our proposal for our new objective, received feedback and agreed on direction.



Project Plan

Third Meeting with LiFETIME

First full team meeting.
Presented our progress and discussed fixing our errors.

Friday 24th

Monday 27th

Tuesday 4th

Thursday 6th

Final Presentation

Interim Presentation

Presenting our progress and our new direction, specifically how we plan to use the remaining time.

Documentation Completion