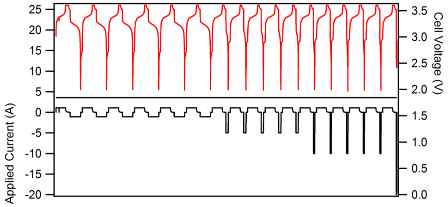
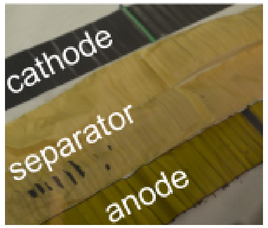
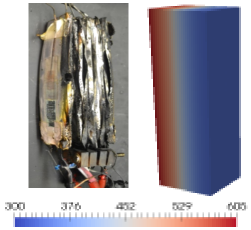
SAND2021-12729C

Sandia National Laboratories

Battery Archive – A Public Battery Data Repository







PRESENTED BY

Yuliya Preger, Valerio De Angelis

DOE OE Energy Storage Peer Review 2021

October 28, 2021

U.S. DEPARTMENT OF ENERGY NNSA

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PROJECT OVERVIEW

SUMMARY: Develop a user-friendly platform to make battery performance data and analysis from a variety of institutions accessible to the broader public

SIGNIFICANCE:

- In an increasingly electrified world, many people need battery data for projects and decision making, but few have access to it
- A broad range of battery data (more than a single institution can generate) is needed for developing generalizable performance models

ALIGNMENT WITH CORE MISSION OF DOE OE:

- Energy storage systems contribute to resilience, reliability, and flexibility of energy infrastructure
- Partnering for dissemination of battery performance data can facilitate risk assessment and 'best practices' operation of energy storage technologies

PROJECT OBJECTIVES

Target: simple enough for casual users to compare battery performance, but still useful for advanced modeling

User Problem	Product Feature
Access reliable battery data	Open access repository of battery data with links to studies
Determine if data is relevant before investing a lot of processing time	Immediately visualize the data
Analyze diverse battery data	Standardize data into common format and offer modeling through Jupyter Notebook
Reorganize battery data	Adopt a standard minimum set of metadata, but plan for additional optional metadata
Contribute battery data from different sources	Import data from Excel, battery testers, online repositories (Google Sheets), and databases

PREVIOUS METHODS FOR SHARING BATTERY DATA

Battery data is mostly shared as figures in publications; extracting data is time consuming

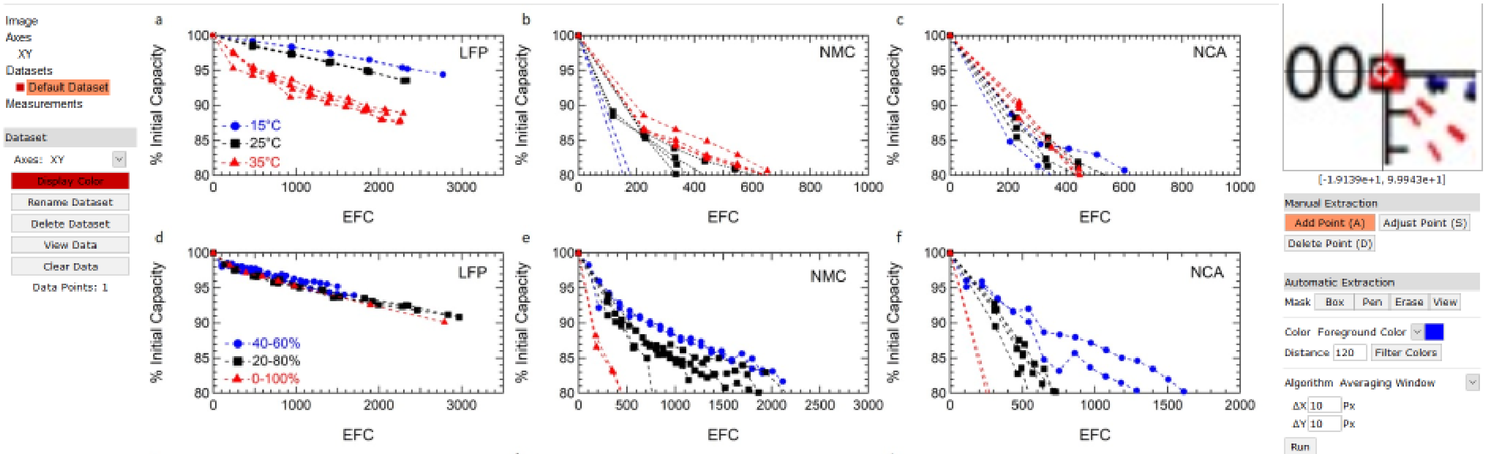
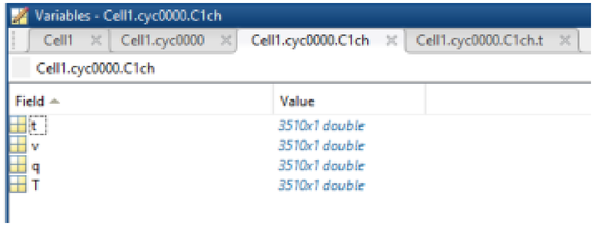


Figure: Preger et al. *J. Electrochem. Soc.* **2020**, *167*, 12; Data extraction: WebPlotDigitizer

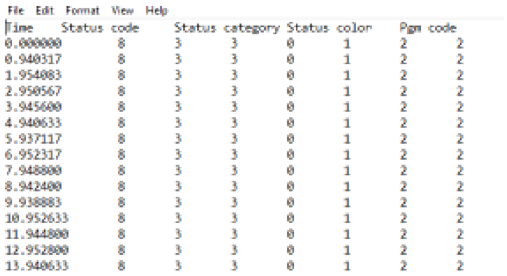
Even when raw data are available, they are not standardized

Matlab



Oxford Battery Intelligence Lab

txt



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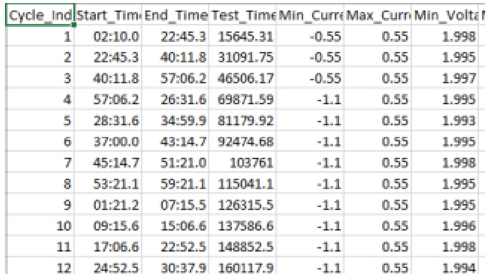
```

CALCE Battery Group

Excel



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1	02:10.0	22:45.3	15645.31	-0.55	0.55	1.998
2	22:45.3	40:11.8	31091.75	-0.55	0.55	1.995
3	40:11.8	57:06.2	46506.17	-0.55	0.55	1.997
4	57:06.2	26:31.6	69871.59	-1.1	0.55	1.995
5	28:31.6	34:59.9	81179.92	-1.1	0.55	1.993
6	37:00.0	43:14.7	92474.68	-1.1	0.55	1.995
7	45:14.7	51:21.0	103761	-1.1	0.55	1.998
8	53:21.1	59:21.1	115041.1	-1.1	0.55	1.995
9	01:21.2	07:15.5	126315.5	-1.1	0.55	1.995
10	09:15.6	15:06.6	137586.6	-1.1	0.55	1.996
11	17:06.6	22:52.5	148852.5	-1.1	0.55	1.998
12	24:52.5	30:37.9	160117.9	-1.1	0.55	1.994

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This makes it difficult to compare results from different studies and do larger-scale analyses

PREVIOUS PUBLIC BATTERY DATA SOFTWARE RESOURCES

Existing resources are useful, but address different problems

Data Management

BEEP (Battery Evaluation and Early Prediction): Open-source, Python-based package parses and featurizes battery cycling data to enable cycle life prediction

cellpy: Open-source, Python-based package parses and enables manipulation of Arbin cycling data

Universal Battery Database: Open-source, Python-based package can be used for managing Li-ion cell data.

Electrochemical Impedance Spectroscopy (EIS)

EIS: Measurement Model Program: software identifies the error structure of EIS measurements and fits custom models to the data

impedance.py: Open-source, Python-based package for EIS data contains modules for data preprocessing, validation, model fitting, and visualization

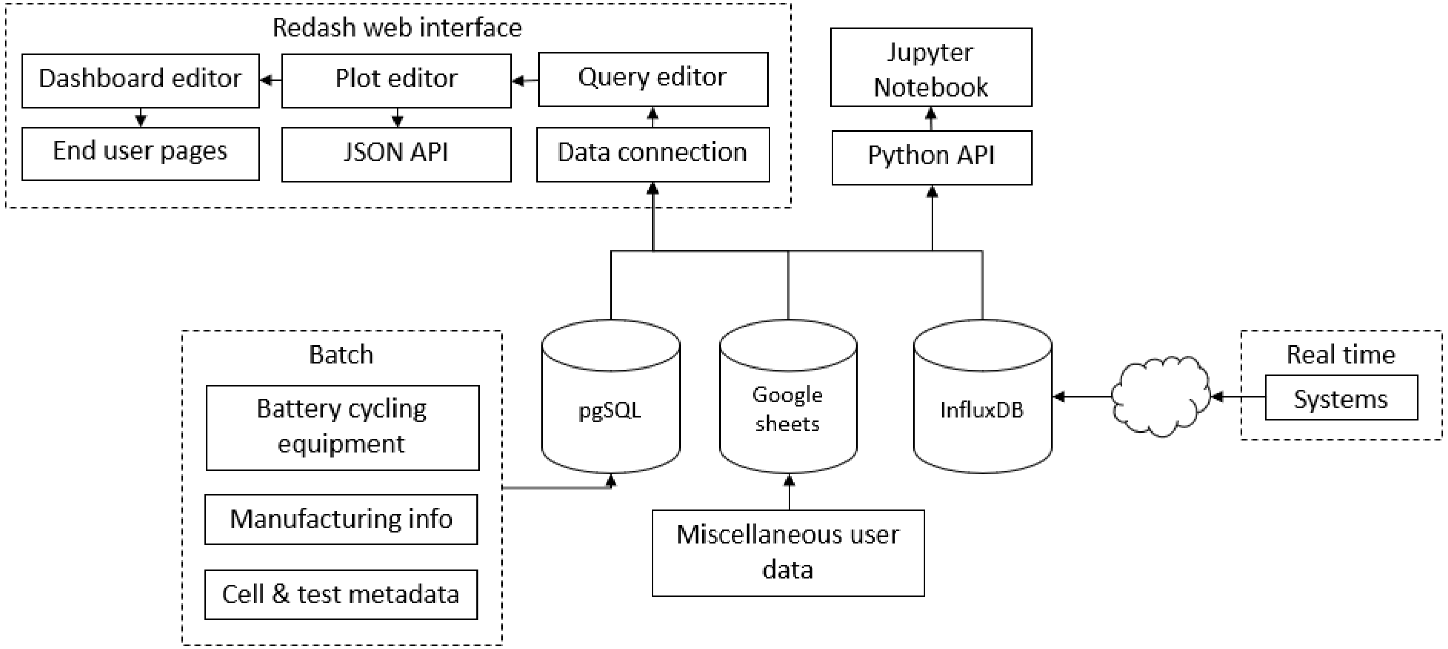
General Modeling

CAEBAT: Various software tools for multi-scale battery modeling and pack design

PyBaMM (Python Battery Mathematics Modeling): Open-source, Python-based package uses various physics-based models to simulate physical properties such as voltage, concentration, and temperature of a Li-ion battery operated under different experimental protocols

PROJECT METHODOLOGY

- We adapted well-established open-source software tools that manage/visualize data for use in the battery community
- We developed the Battery Lifecycle Framework (BLC) - a platform that provides tools to visualize, analyze, and share battery data through the technology development cycle
- BLC has four components: (1) data importers, (2) one or more databases, (3) a front-end for querying the data and creating visualizations, (4) an application programming interface to process the data

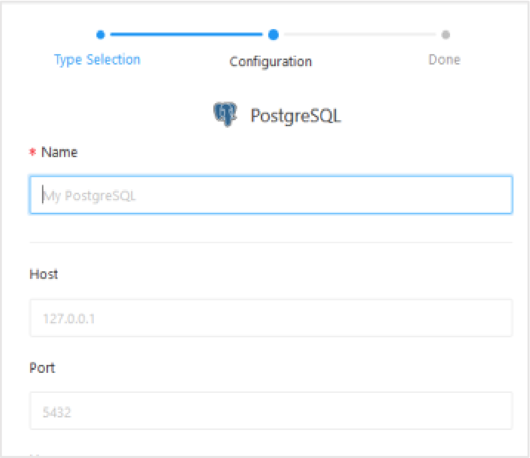


Preprint: https://ecsarxiv.org/h7c24; Github: https://github.com/battery-lcf/battery-archive-sandbox

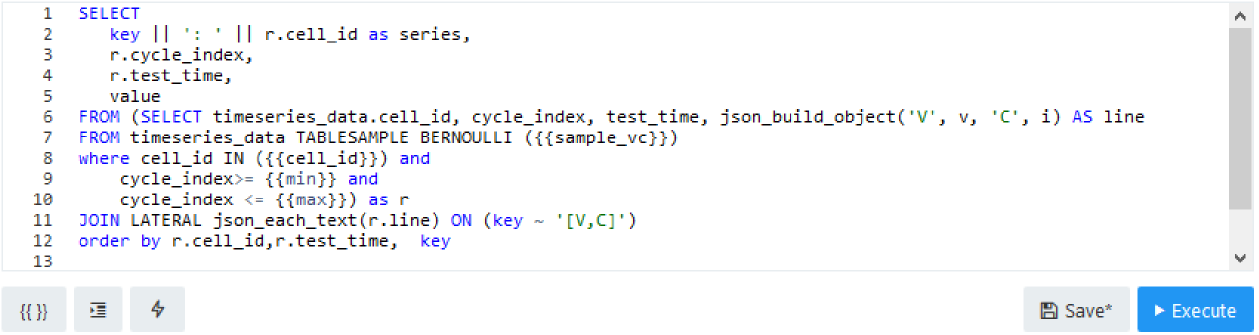
PROJECT METHODOLOGY – LEVERAGING REDASH

Redash is an open-source extract-transform-load tool with a robust web management interface that can be used to manage data connections and generate visualizations. It offered the foundation around which we built battery-specific software tools.

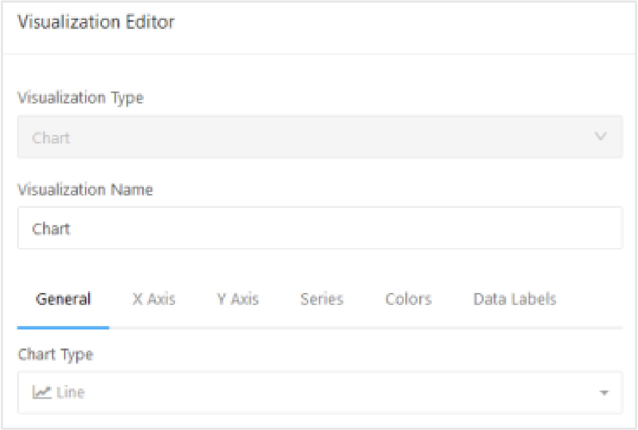
1) Create new data source



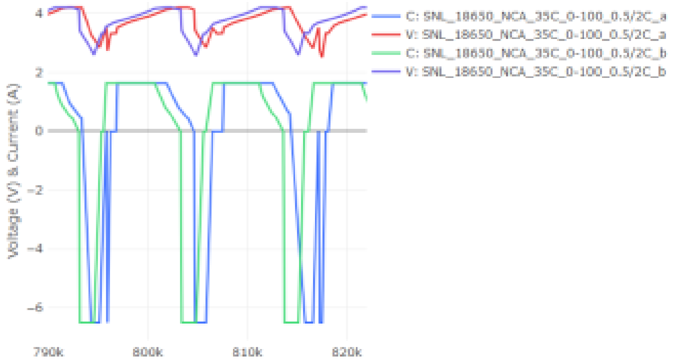
2) Build data queries



3) Build visualizations



4) Manipulate plots

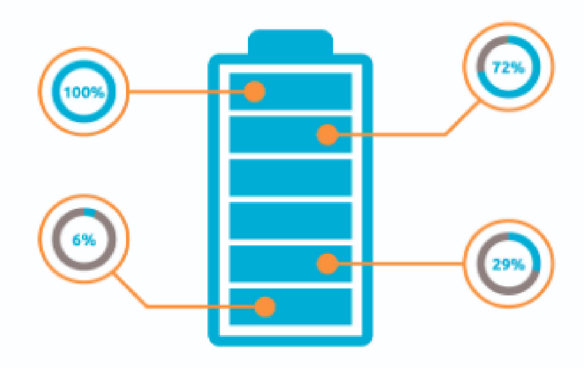


PROJECT RESULTS: FIRST MULTI-INSTITUTION BATTERY CYCLING DATABASE

BatteryArchive.org

A repository for easy visualization, analysis, and comparison of battery data across institutions

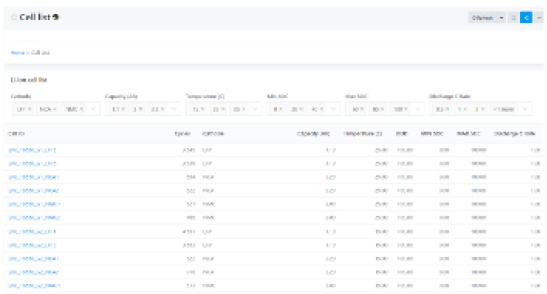
View Data



Features

1

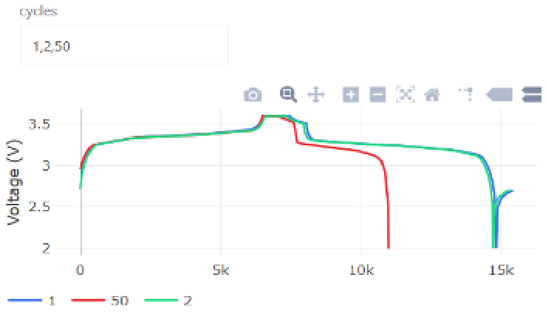
Filter battery data



Query and filter for specific experimental conditions.

2

Visualize and compare data



Display battery data, including voltage curves and capacity fade.

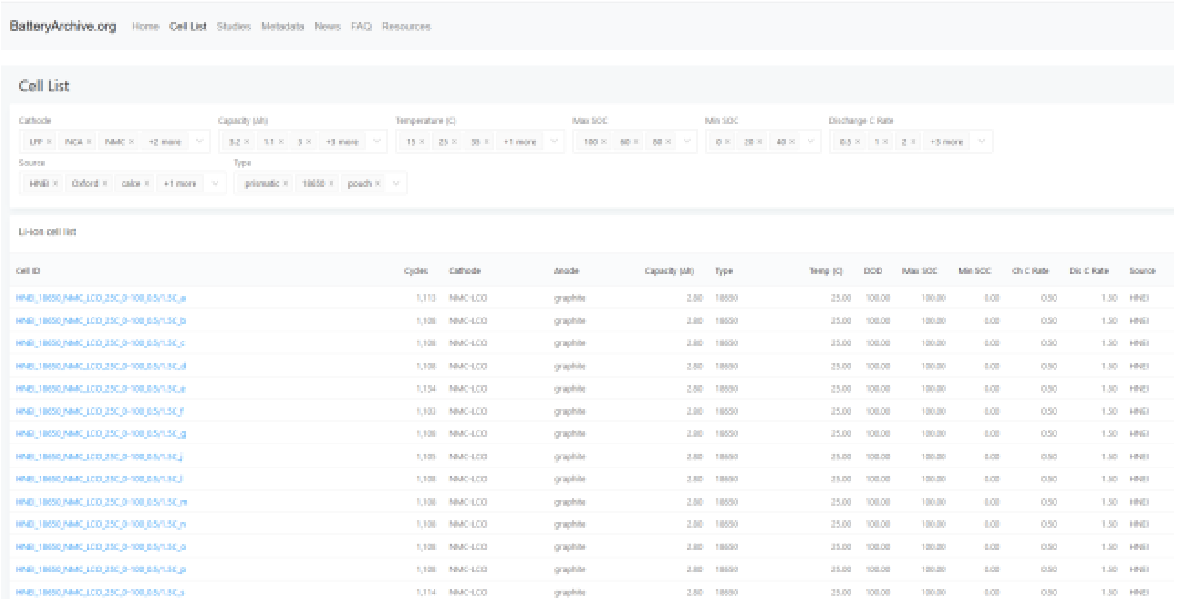
3

Compare data with models

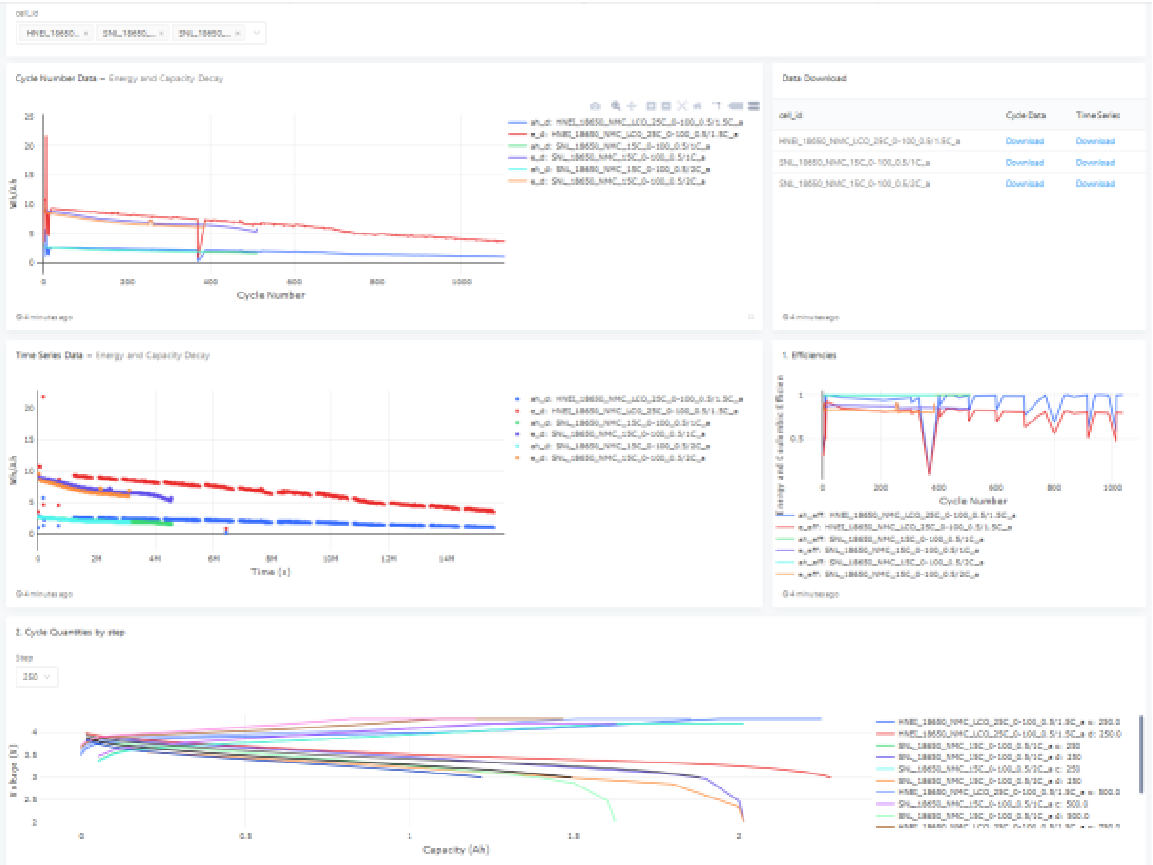
Apply performance and degradation models to battery data.

PROJECT RESULTS: IMMEDIATE PRESENTATION OF COMMON BATTERY DATA VISUALIZATIONS

Search database by metadata related to cell + cycling conditions



Capacity and energy decay, efficiencies, and voltage curves automatically plotted for selected cells

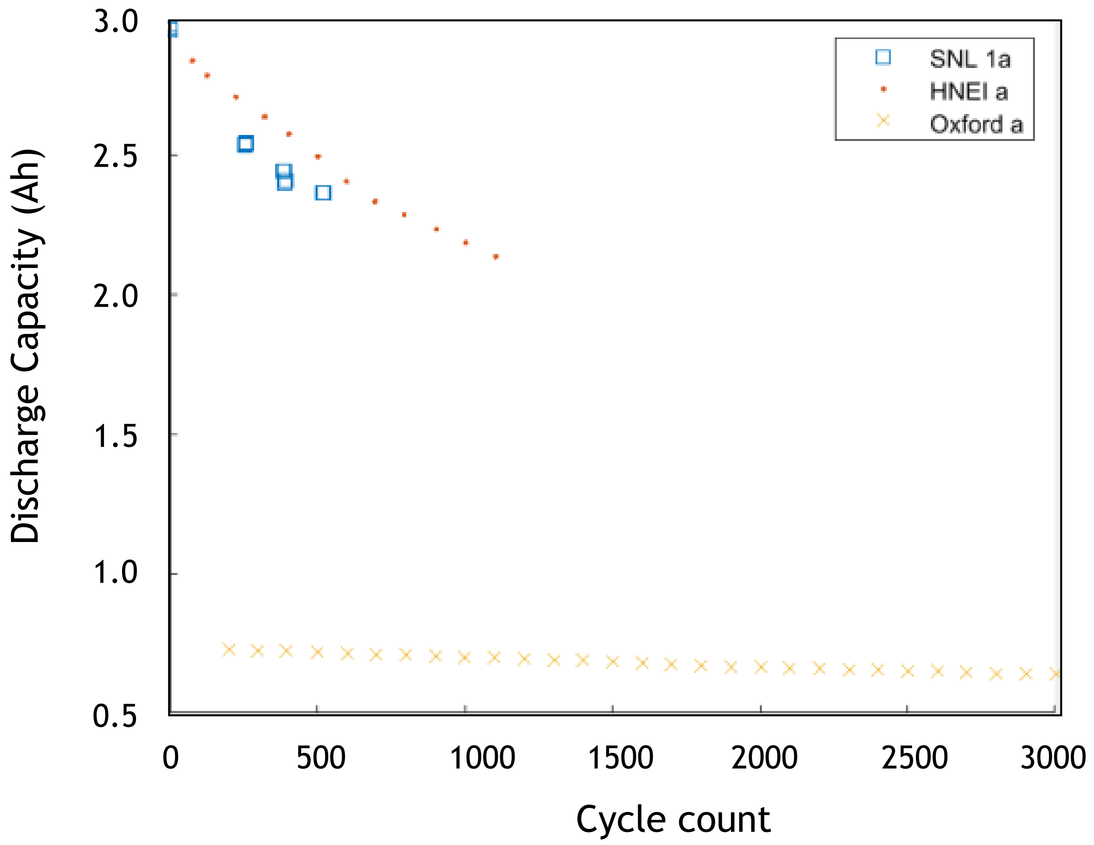


PROJECT RESULTS: EASY TO RUN ANALYSIS ON MULTIPLE DATASETS

Development of importers to transform data into a common format enables comparison across studies and saves users many hours on pre-processing. We are pre-populating the site with generalizable analysis scripts.

Example: extracting 'capacity check' cycles from 'bulk cycling' conditions

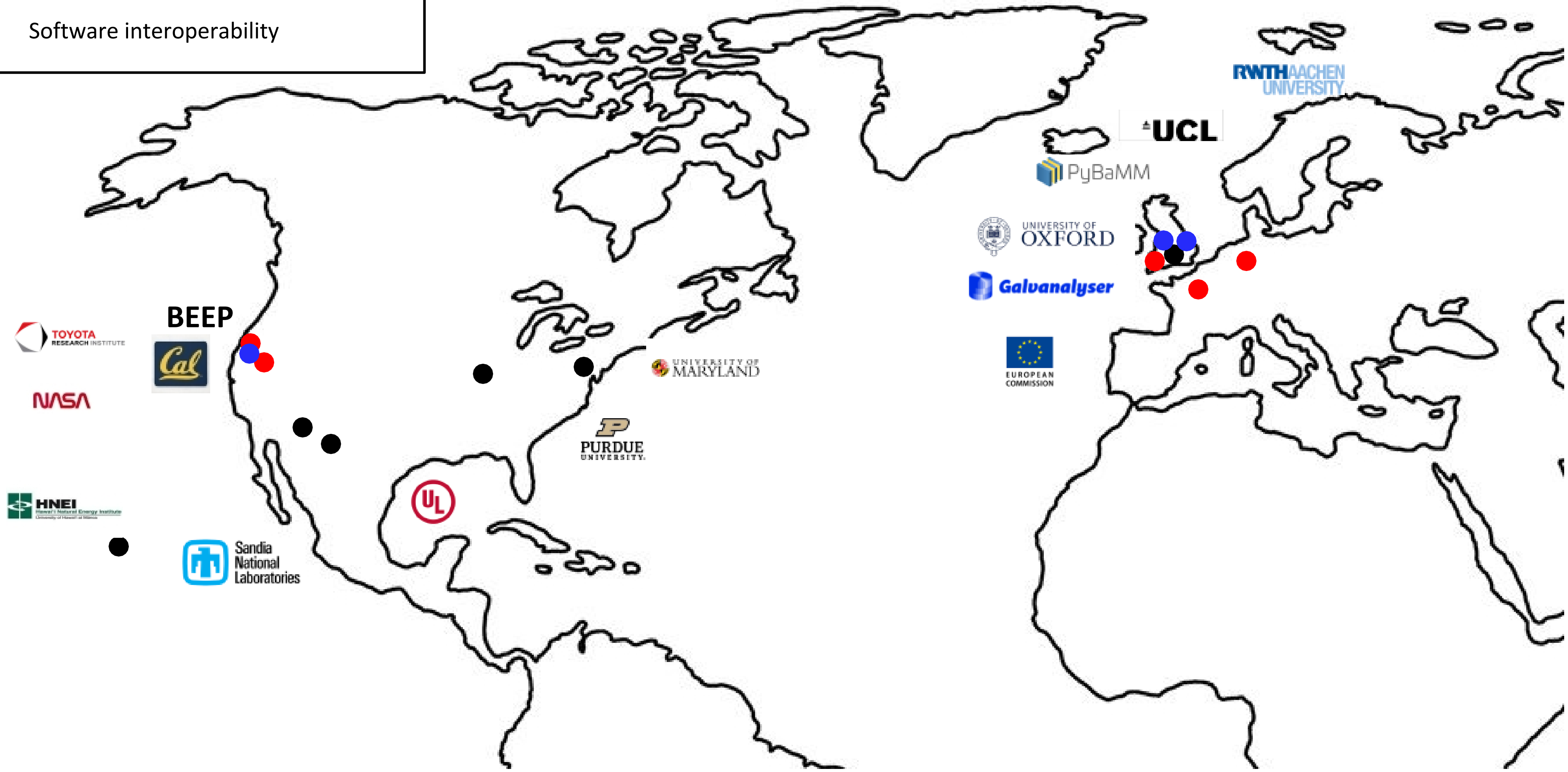
- One cell from each of three datasets from three different institutions, each with a different original file format
- All three datasets had a different routine for capacity checks
- A single script was developed to extract the capacity check cycles from all datasets



PROJECT IMPACT: NETWORK OF CONTRIBUTORS

Sources of datasets & collaborators

- Datasets online
- Datasets in pipeline
- Software interoperability



PROJECT IMPACT: USER STORIES

Over 5500 site users, many return visits, from over 50 countries, academia and industry

- Developers of non-battery energy storage technologies wanting to understand how their products compare to batteries under different conditions
- Representatives of utilities installing energy storage systems who are trying to get a better sense of what conditions exacerbate battery degradation
- Researchers in universities and companies who are trying to validate their battery degradation models with more data + class projects for undergrads
- Battery software start-ups which need data to test their ideas and product (new data collection would be expensive)
- Individuals at companies that already have a lot of battery data (running quick tests to try out a new idea, accessing data for different batteries, etc.)

PROJECT RESULTS: EXTENDING THE SOFTWARE TO OTHER APPLICATIONS

The flexible software package can be extended to many other public and private battery data applications. Software compatibility allows data exchange between public and private tools as needed (e.g. some private data is shared publicly and some public data is downloaded for analysis in a private repository).

Battery Archive public site
(cycling data)

Battery start-up internal data management
(compiling all lab testing data)

Battery Lifecycle Framework - a platform that provides tools to visualize, analyze, and share battery data through the technology development cycle

Battery start-up internal data management
(linking data from cell materials, lab cell testing, manufacturing, and fielded systems)

ORNL-SNL public battery abuse database
(thermal runaway data)
**See Presentation #605, Hsin Wang

SUMMARY OF INNOVATIONS

- First public multi-institution battery cycling database has given data access to people all over the world in a variety of industries

- Data standardization has saved users many hours on pre-processing and enables the development of generalizable battery models

- Battery Lifecycle Framework offers a complete battery-oriented open-source software package (import, visualization, analysis) that can be easily customized for different applications

FUTURE DEVELOPMENT

- Improve the UX in collaboration with a web firm
- Enable interoperability with other open-source battery software packages (e.g. BEEP, PyBaMM)
- Develop more pre-built queries/plots for other kinds of battery data analysis
- Publish a JSON API to exchange data
- Continue uploading data to the Battery Archive public site

*All features added to Battery Archive will be incorporated into the open-source software package

PROJECT ACKNOWLEDGMENTS

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Software development: Ammar Safdari, Stephen Bauer, Irving Derin
Early framework testers at CUNY Energy Institute: Sanjoy Banerjee, Jinchao Huang, Andreas Savva, Gautam Yadav
Front end: Sam Roberts-Baca (SNL)
Database: Mark Spoonamore (SNL)
Early site feedback: Matthieu Dubarry (Hawaii Natural Energy Institute)

BEEP integration: Patrick Herring (Toyota Research Institute)

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Public site: www.BatteryArchive.org
Battery Lifecycle Framework Preprint: https://ecsarxiv.org/h7c24
Github: https://github.com/battery-lcf/battery-archive-sandbox

For questions about this presentation: ypreger@sandia.gov