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Battery Intelligence

Software for Data-Driven Battery Engineering

Eli Leland

Co-Founder & Chief Product Officer

AEC 2018

New York, NY

4/2/2018

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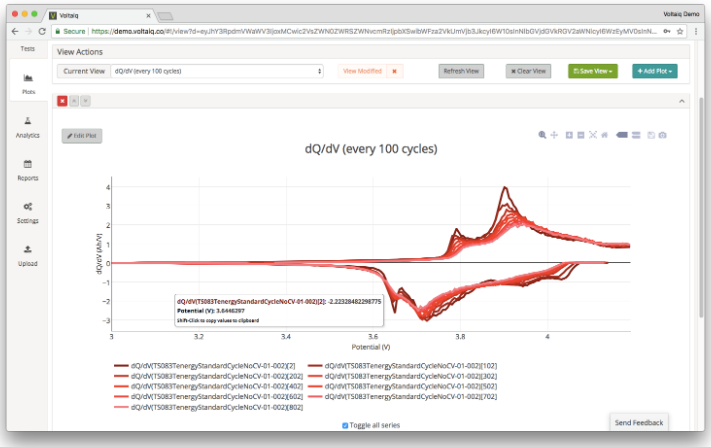
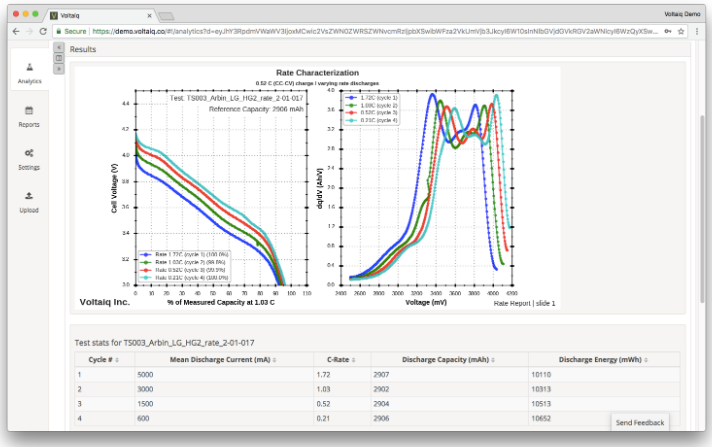
Voltaiq is a Battery Intelligence software company with the mission to bring your battery technology to market faster

- Software company founded in 2012 by battery engineers and data scientists
- Customers include Fortune 500, leading universities, cutting-edge startups
- Applications across consumer electronics, medical, EVs, and energy storage
- Offices in Brooklyn, NY, Berkeley, CA, and opening soon in Europe





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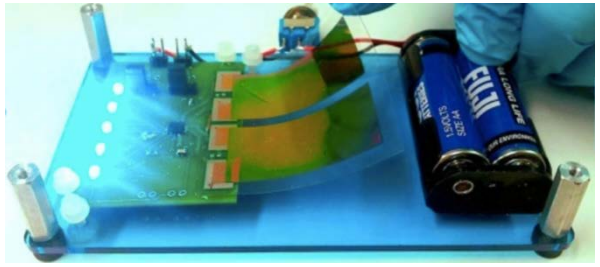
We started Voltaiq to solve our own problems leading two ARPA-E research projects at the CUNY Energy Institute

Grid-scale battery and printed capacitor R&D projects

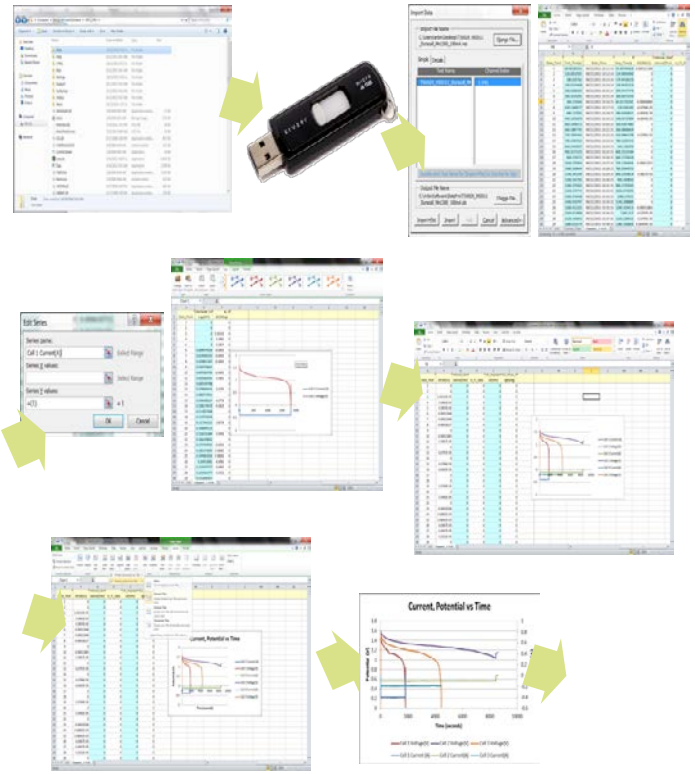
Tal Z. Sholklapper, PhD
ARPA-E GRIDS
Flow-Assisted Alkaline Battery

Eli S. Leland, PhD
ARPA-E ADEPT:
Metacapacitors for Power Conversion



Thousands of prototypes to test

Huge data analysis challenges



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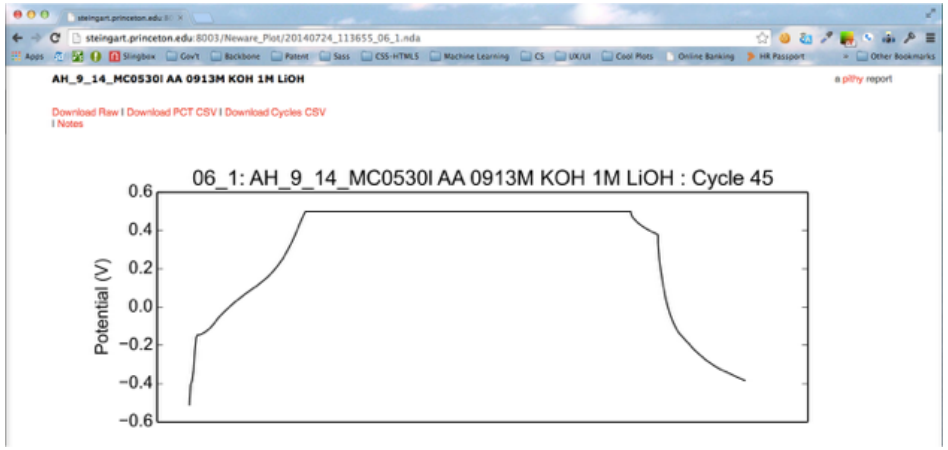
Our group developed some rudimentary software tools to enable basic data analysis in a web browser

Huge data analysis challenges

A simpler, more sane way to analyze data



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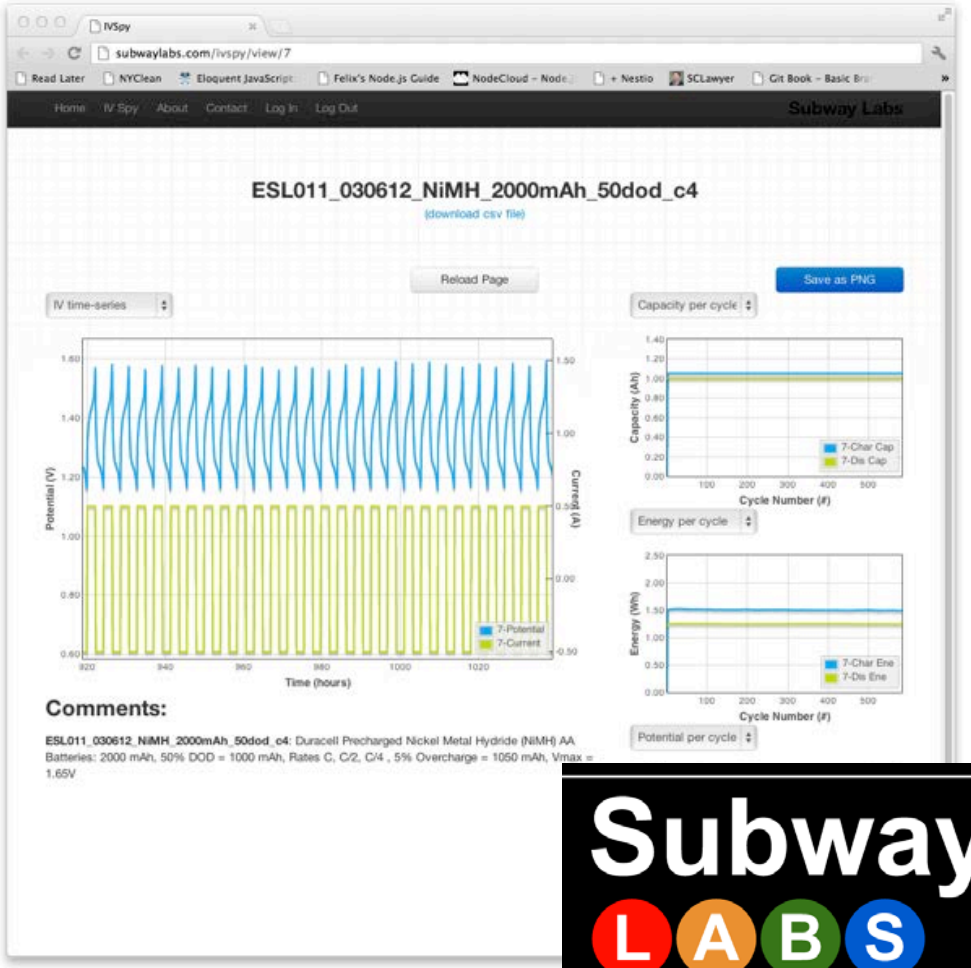
Early commercial interest led to the formation of Subway Labs, and a proof-of-concept deployment of our first product, ***IV Spy***



Subway LABS

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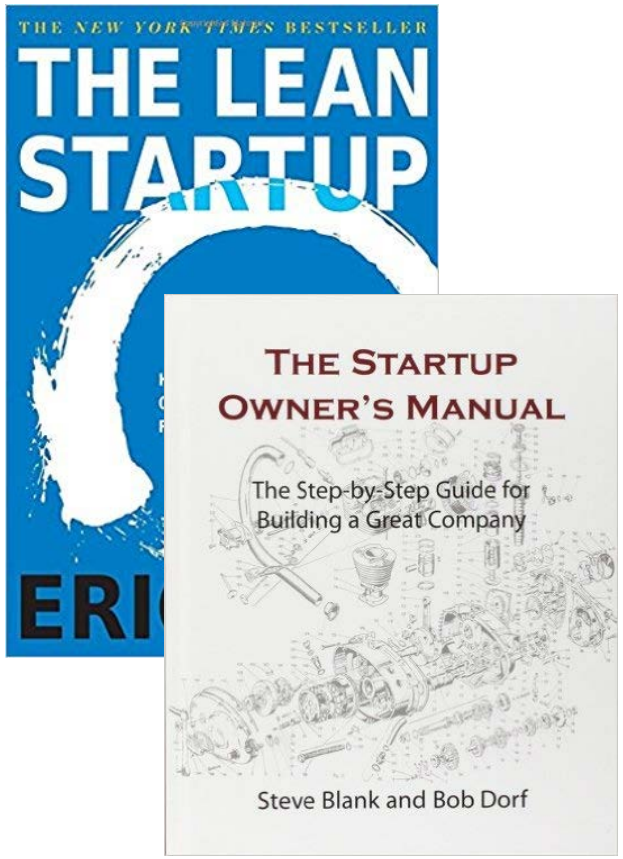
Buoyed by this early success, we set about building a company — SBIR support from the DOE and NSF was vital early on

We read the books



Called everyone we knew

(and convinced ourselves there was a larger opportunity)

And secured SBIR funding

Office of Science
ASCR

Phase 1 & 2
$1.15m total

Industrial Innovation and Partnerships

Phase 1 & 1b
$200k total

Along the way be came up with a better name

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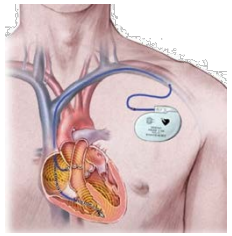
Companies across industries are making high-stakes engineering decisions around what batteries to use and how to use them

Batteries power products that are more complex and expensive than ever before

Batteries must be safe



They must be reliable for years of use

They must be integrated into large systems

Poor choices can have disastrous impact on brand equity and balance sheet

Samsung Galaxy Note 7 explosions

HP's 50,000 laptop recall over fire risk

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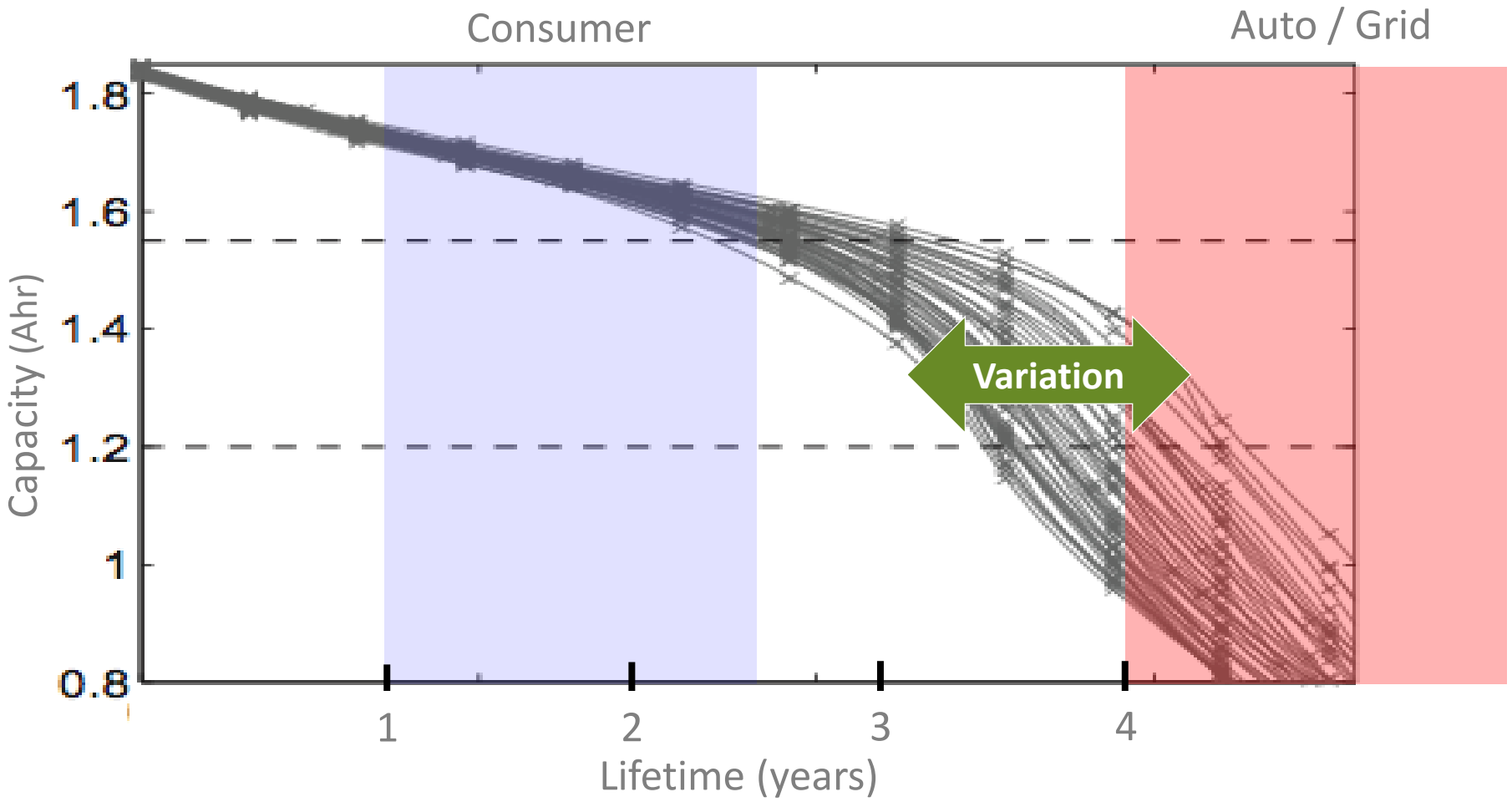
Longer application lifetimes are presenting new challenges



T. Baumhofer et. Al. / Journal of Power Sources 247 (2014) 332-338

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High-level statistics such as battery capacity don’t tell you enough

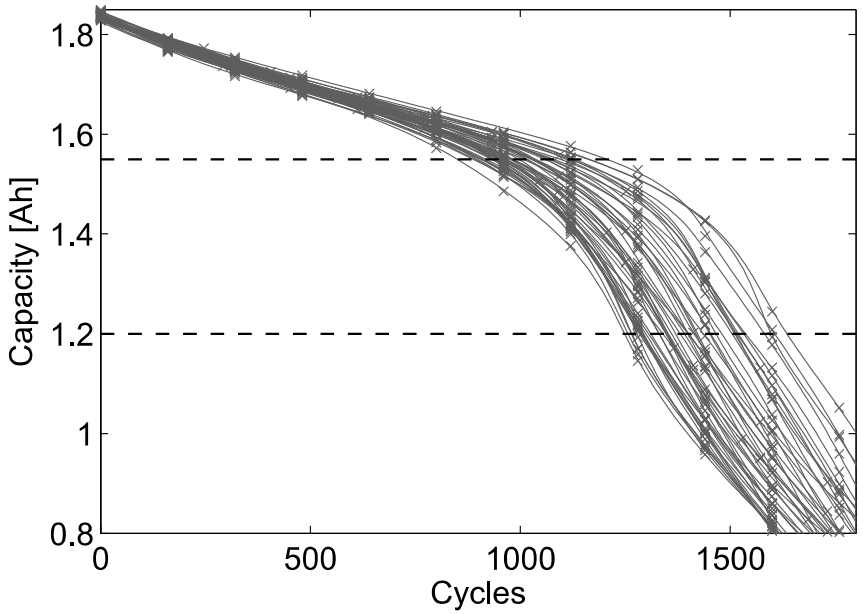

Fig. 6. Different aging trends from 48 equal cells under same aging conditions and profiles.

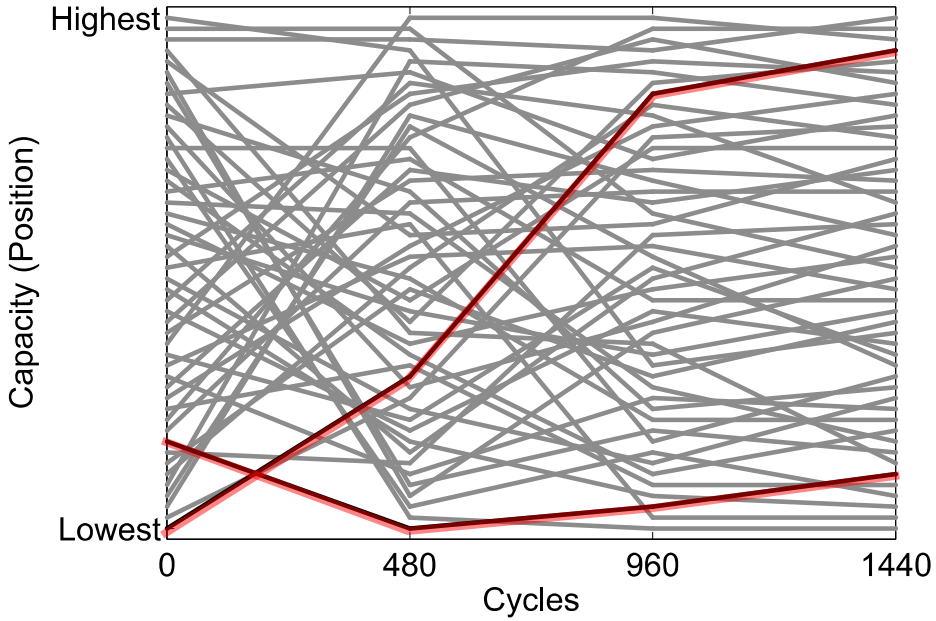

Fig. 7. Development of the position of the 48 cells within the sorted capacity at four cycle lifetimes.

Minimal correlation between capacity early and late in the life cycle

T. Baumhofer et. al. / Journal of Power Sources 247 (2014) 332-338

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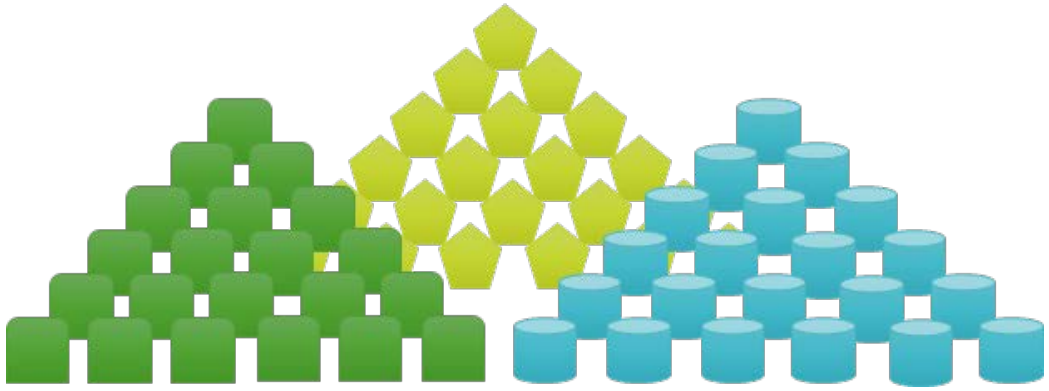
Developing safe and effective battery products has a time problem
Testing and analysis is time consuming and inefficient

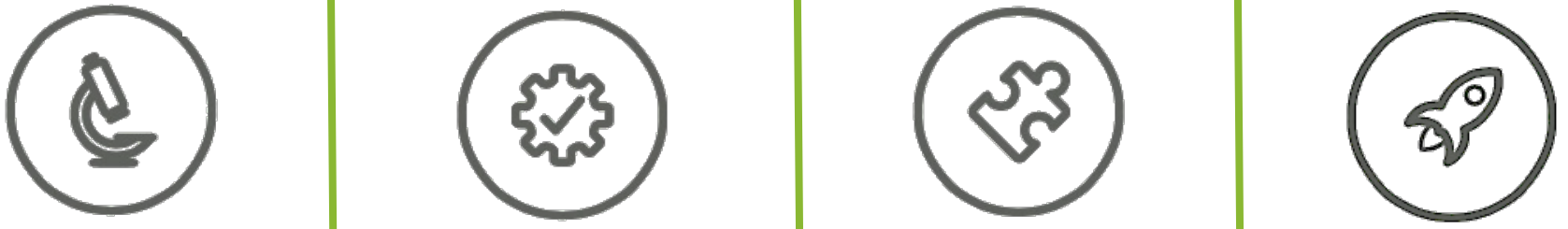
Data outputs-too many files, too many formats



Makeshift analysis tools

Data isn't shared across the industry value chain

R&D | Manufacturing | Integration | Field



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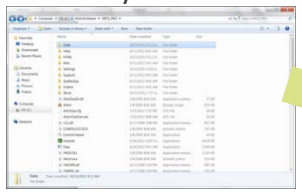
Voltaiq gets battery-powered products to market faster, lowers engineering costs, and decreases risk

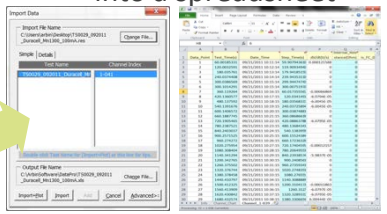
Typical battery analysis workflow

Search **thousands of files** to find your data

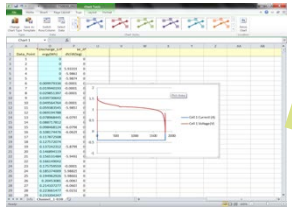


Transfer data files to a flash drive

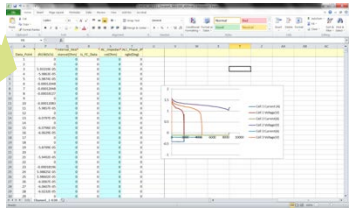
Import the first data file into a spreadsheet



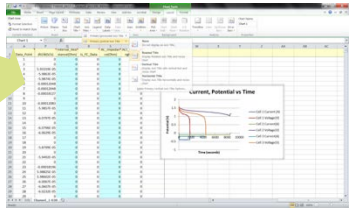
Plot data series, **one-by-one**



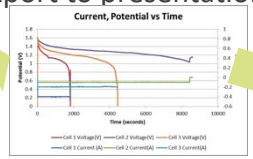
Repeat import and plotting for each additional test result



Modify plot options for each plot



Export to presentation or email



Repeat for each type of plot

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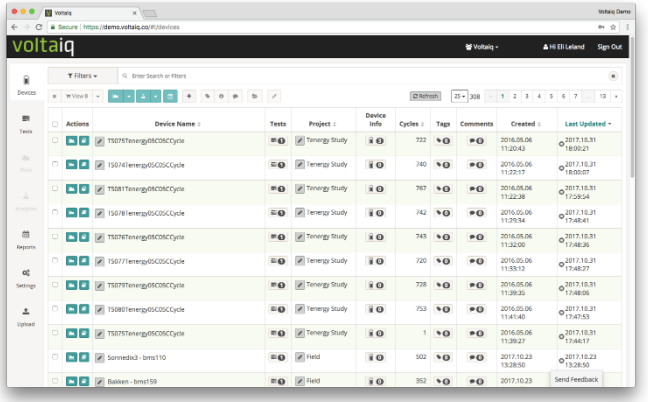
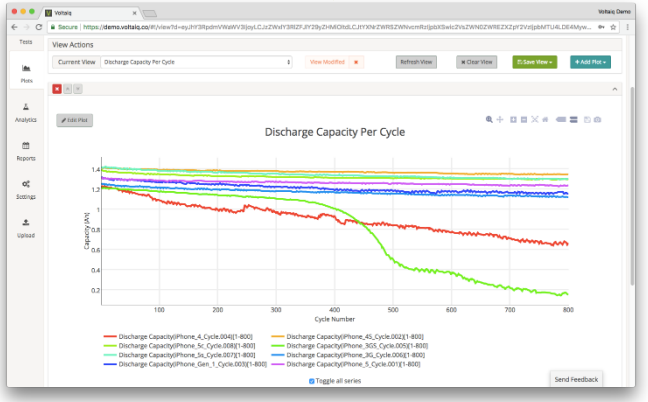
Select current and historic data to compare, from a single database



Analyze in browser, share by links



Boost equipment utilization 30% — Save time equal to multiple FTEs

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Voltaiq aggregates data across sources, harmonizes that data on a cloud platform, and provides in-depth performance analytics

Battery cyclers and systems in the field generate data

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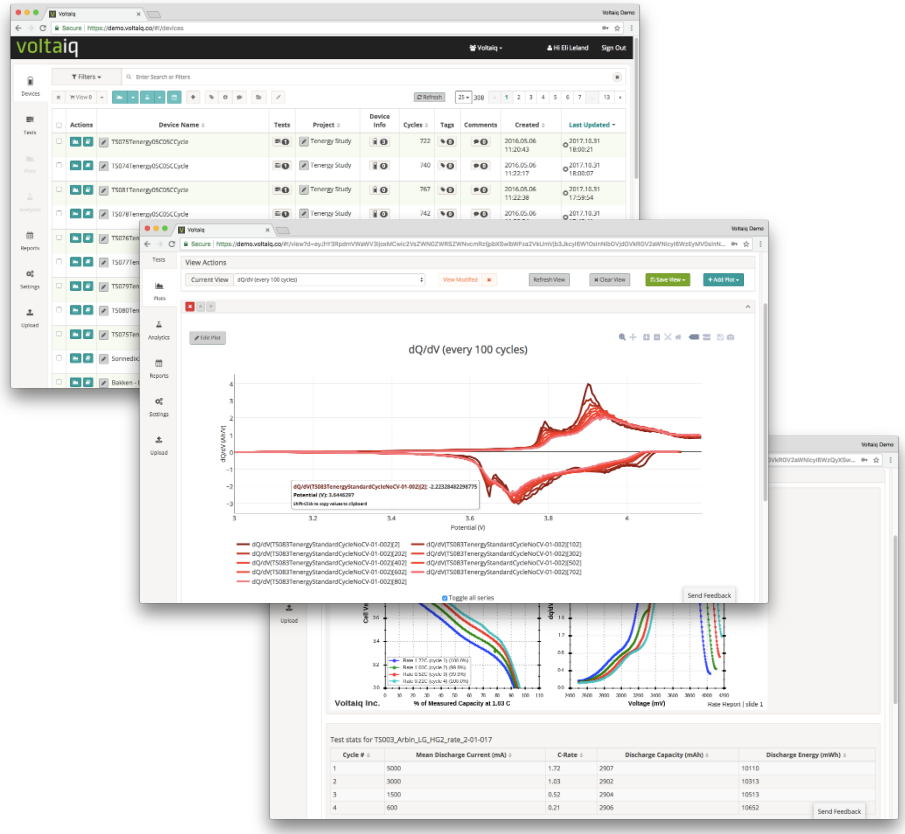
Data is automatically centralized and harmonized in Voltaiq



Quickly find, visualize, compare, and analyze performance

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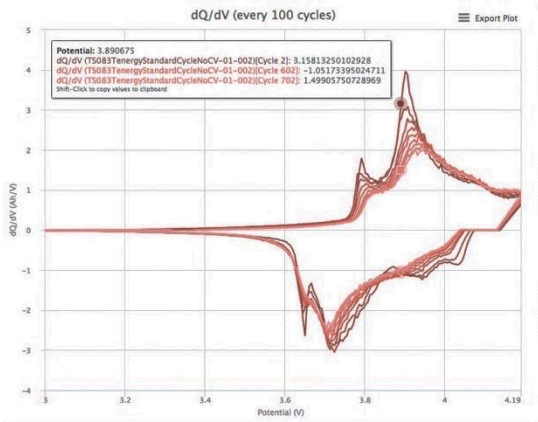
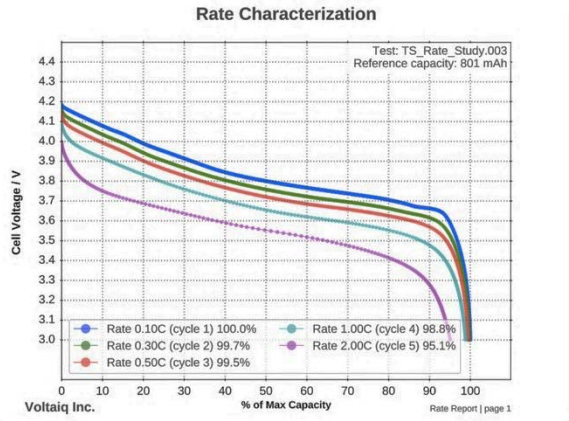
Voltaiq Battery Intelligence software engineering modules

Voltaiq Core



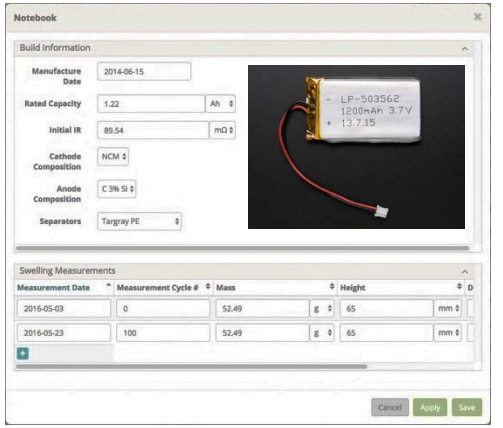
Rapid **interactive** data **visualization**, powerful **search**, seamless **sharing** and collaboration with colleagures, near and far

Voltaiq Analytics*



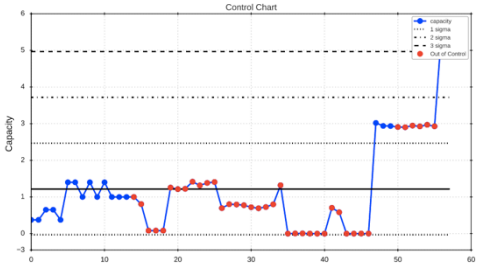
Powerful **custom analysis** of your entire dataset: Statistical studies, pass/fail **automation**, specialty analysis (HPPC, capacitor ESR), production **statistics**

Voltaiq Notebook*



Record and **track** battery **materials**, processing, test conditions, changing **dimensions**, and **observations**, and analyze values alongside performance data

Voltaiq Reports*



Cycle Number	Coulombic Efficiency (TS056Tenergy1C02C4t34NoCV.001) [All]	Discharge Capacity (TS056Tenergy1C02C4t34NoCV.001) [All]
0	107.262909008659	0.4442980181
1	1.00758134935466	0.2738455855
2	1.00376263265283	0.2754197681
3	1.00229858182828	0.2740357702
4	0.999443610977948	0.2694173401
5	1.00182413873189	0.2106062471
6	1.00216758938734	0.2060083093

Automated, fully **customizable reports** emailed to your inbox on a scheduled or event-driven basis; The Voltaiq **“Virtual Technician”**

* Optional

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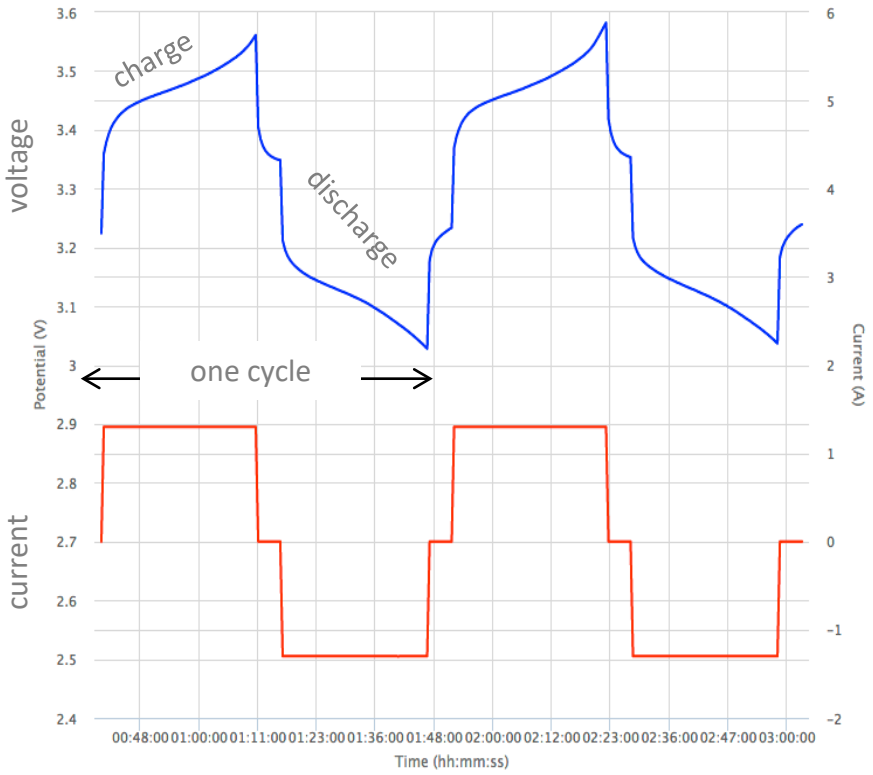
Voltaiq helps you dig deeper to unlock insights hidden in your battery data

From raw time-series current and voltage…



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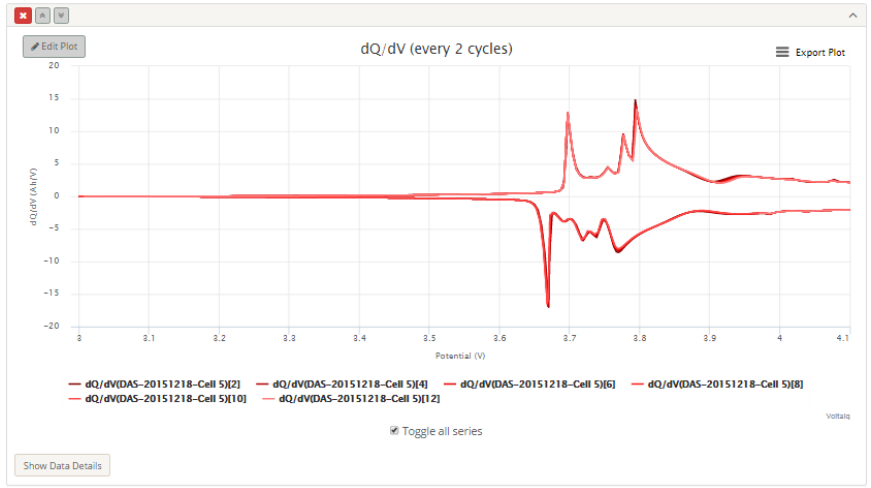
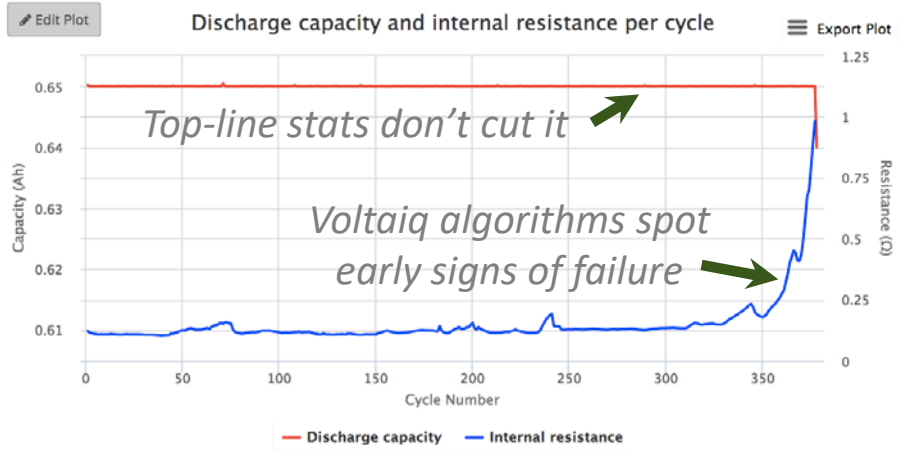
proprietary analytics

Differential capacity analysis



Advanced cycling analysis



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Our analytics derive dozens of additional time-series and per-cycle parameters from all raw data streams

Harmonized time-series values	Aggregated per-cycle values		
Test Time	Cycle Number	Minimum Potential	Cycle Start Time
Timestamp	Charge Capacity	Maximum Potential	Cycle End Time
Datapoint Number	Discharge Capacity	Initial Charge Potential	Cycle Start Timestamp
Datapoint Ordinal	Minimum Test Net Capacity	Final Charge Potential	Cycle End Timestamp
Cycle Number	Maximum Test Net Capacity	Initial Discharge Potential	CV Charge Time
Current	Maximum Cumulative Capacity	Final Discharge Potential	Other Charge Time
Potential	Cumulative Charge Capacity	Open Circuit Potential - Charge	Total Charge Time
Step Index	Cumulative Discharge Capacity	Open Circuit Potential - Discharge	CV Discharge Time
Step Time	Cycle Net Capacity	Relaxation Potential - Charge	Other Discharge Time
Charge Capacity	CV Charge Capacity	Relaxation Potential - Discharge	Total Discharge Time
Discharge Capacity	Other Charge Capacity	Mean Charge Potential (time-weighted)	Rest Time
Charge Energy	Charge Energy	Mean Discharge Potential (time-weighted)	Other Cycle Time
Discharge Energy	Discharge Energy	Mean Charge Potential (capacity-weighted)	Total Cycle Time
	Minimum Test Net Energy	Mean Discharge Potential (capacity-weighted)	Maximum Charge Power
Derived time-series values	Maximum Test Net Energy	Minimum Charge Current	Minimum Charge Power
	Maximum Cumulative Energy	Maximum Charge Current	Maximum Discharge Power
Power	Cumulative Charge Energy	Mean Charge Current (time-weighted)	Minimum Discharge Power
Differential voltage dV/dt	Cumulative Discharge Energy	Minimum Discharge Current	Mean Charge Power (time-weighted)
Differential capacity dQ/dV	Cycle Net Energy	Maximum Discharge Current	Mean Discharge Power (time-weighted)
Current Cycle Net Capacity	CV Charge Energy	Mean Discharge Current (time-weighted)	Internal Resistance Start of Charge
Current Cycle Net Energy	Other Charge Energy		Internal Resistance End of Charge
Test Net Capacity	Coulombic Efficiency		Internal Resistance Start of Discharge
Test Net Energy	Energy Efficiency		Internal Resistance End of Discharge
Test Cumulative Capacity	Voltage Efficiency		
Test Cumulative Energy			

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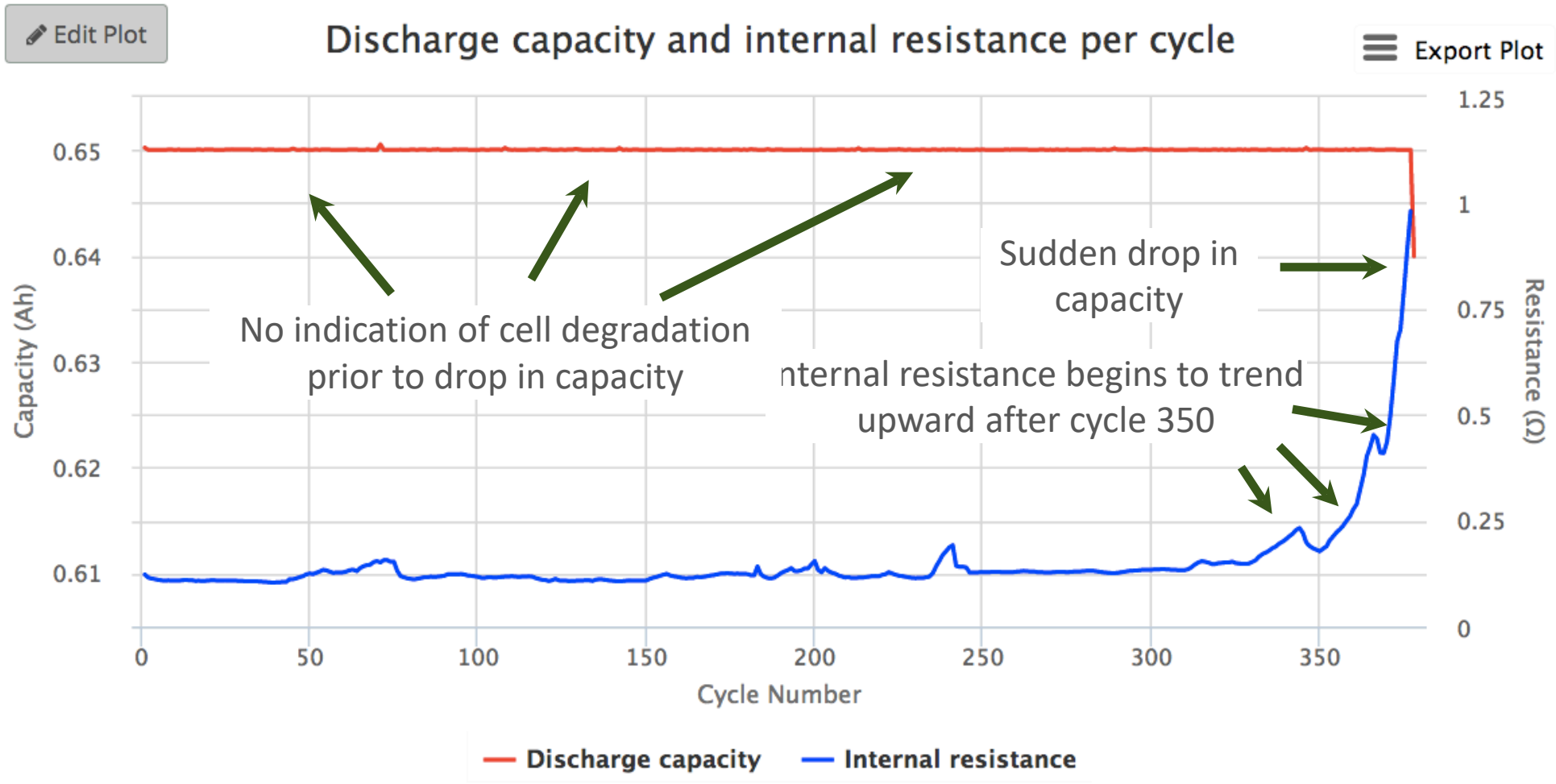
Voltaiq includes predictive analytics built in to spot degradation trends sooner



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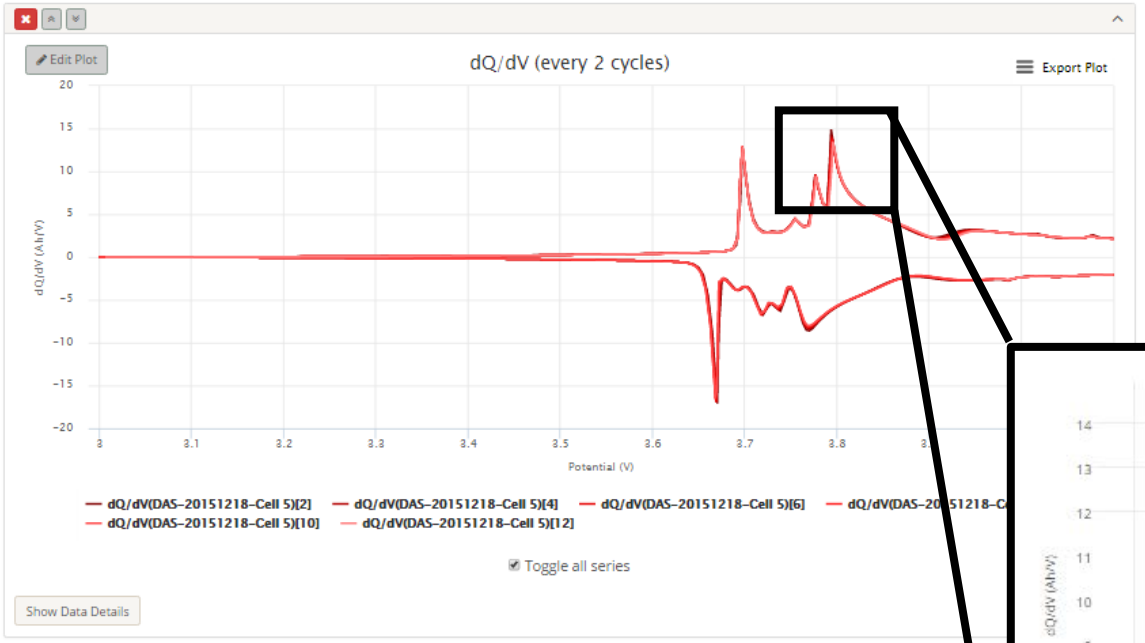
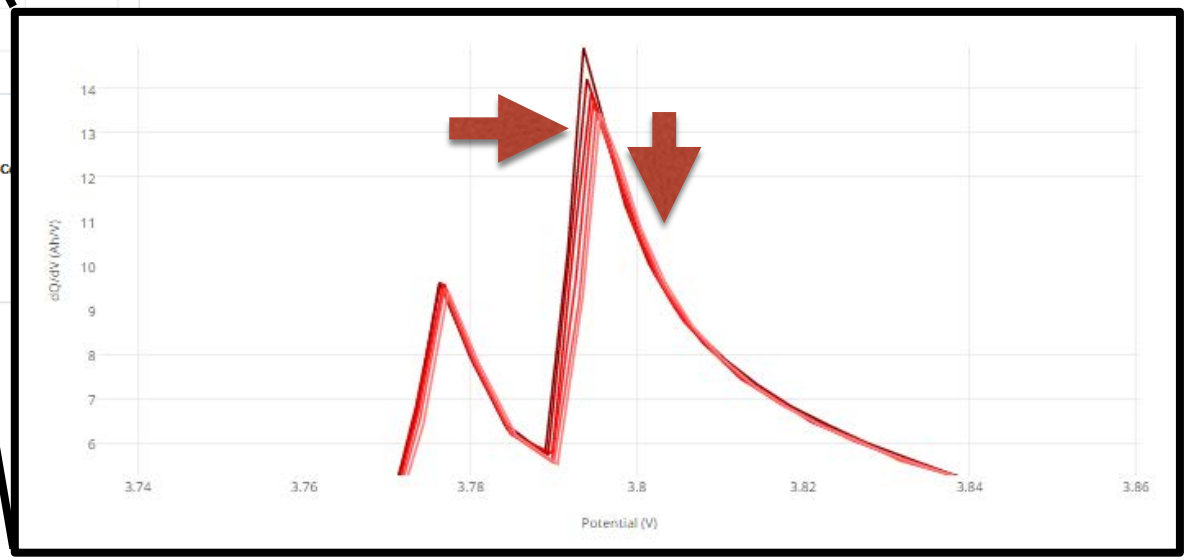
We are developing algorithms that use advanced features extracted from time-series data to provide even greater predictive capability



Change observed in 12 cycles using high-precision battery cyclers!



*Peak position indicates internal resistance; peak height indicates electrode capacity

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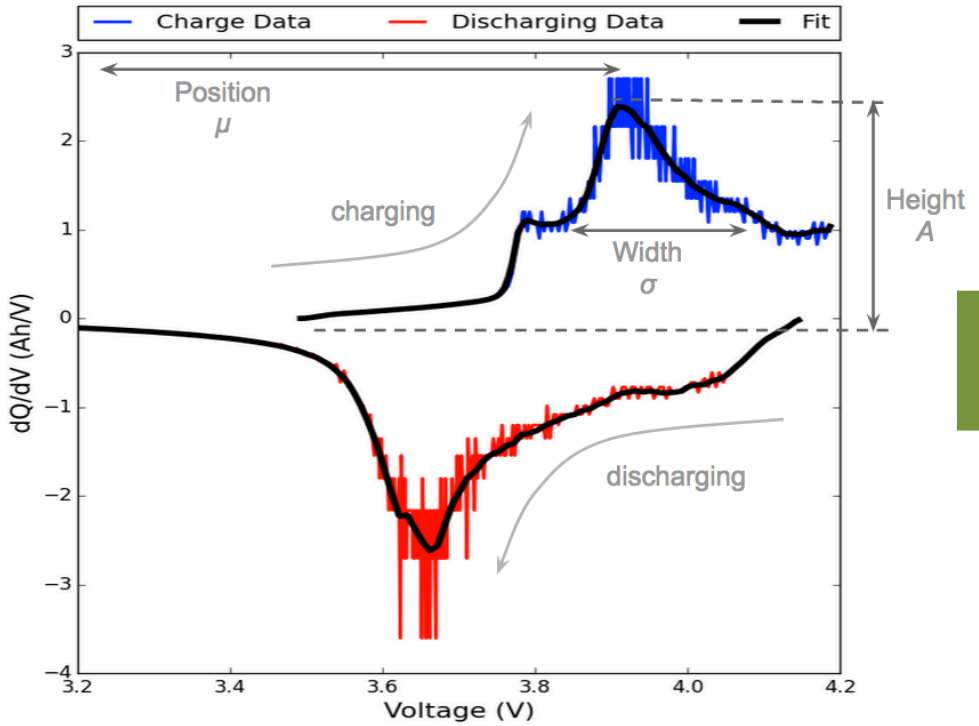
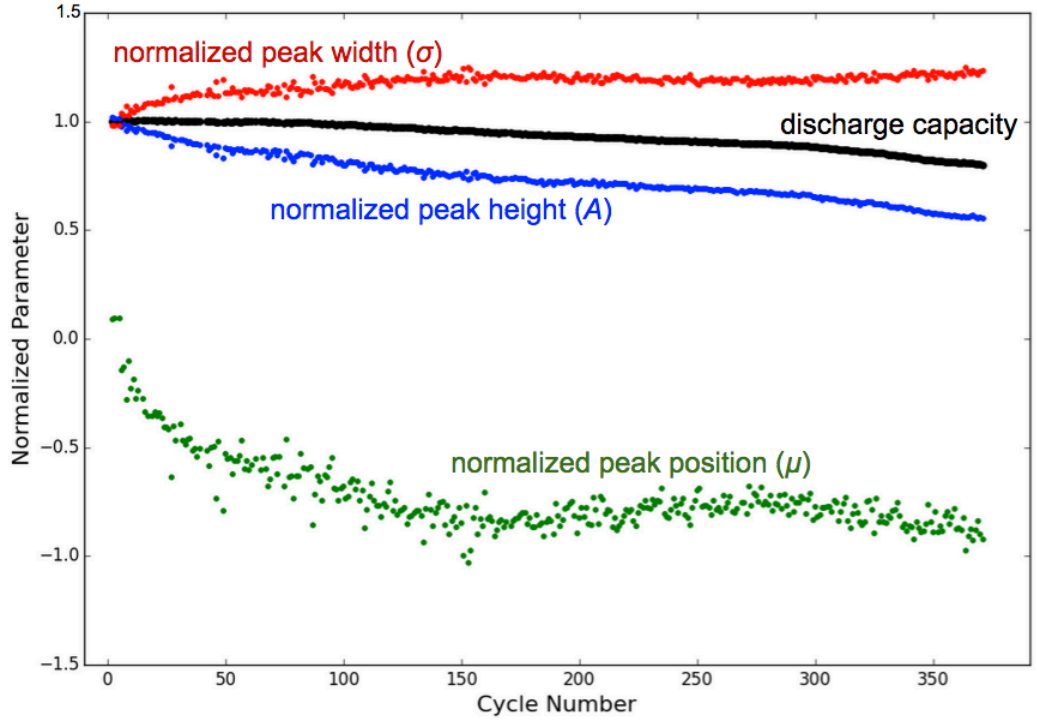
We are developing algorithms that use advanced features extracted from time-series data to provide even greater predictive capability





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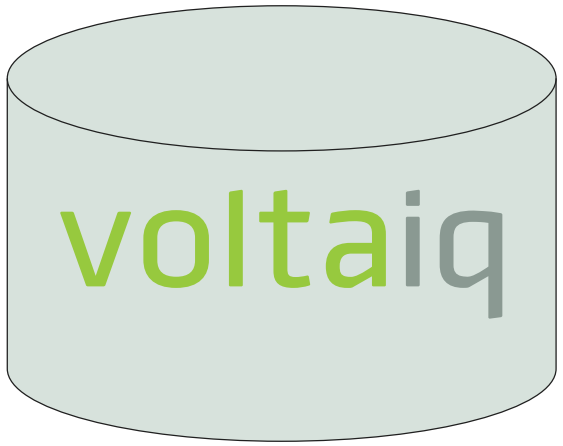
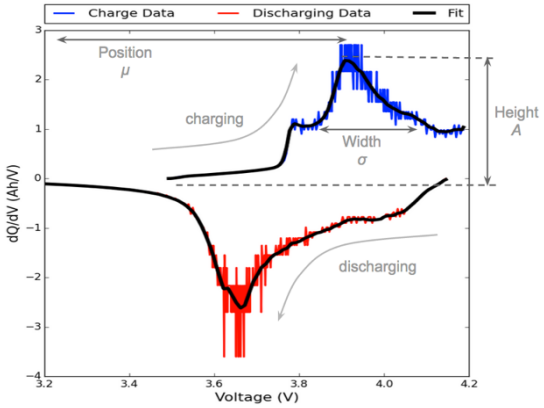
Over time, our data asset and predictive analytics will drive value across the battery supply chain and life cycle

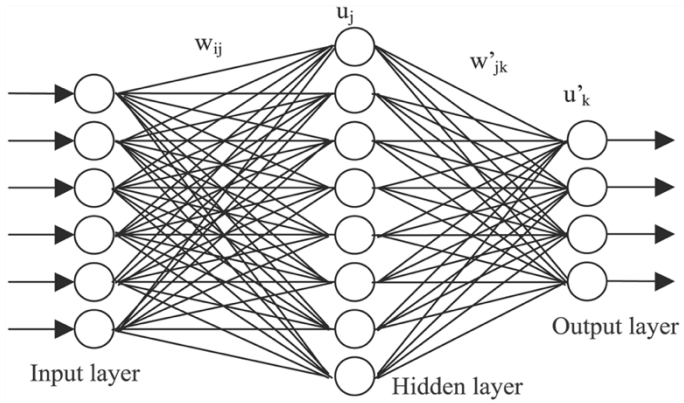
Massive battery performance database



Proprietary analytics



Machine learning



- Predict failure without testing to end-of-life
- Optimize device operation
- Minimize product risks

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Voltaiq is a full lifecycle solution for ensuring high product quality and traceability from materials through end of life

VENDOR

- Was the battery made well with the right materials?
- Is battery quality consistent?

OEM

- Was the battery integrated properly?
- Is the system safe?
- What is the expected lifetime?

USER

- Was the battery used properly?
- Is my warranty valid?
- Did control algorithms maximize value?

2ND LIFE

- How much value can the battery deliver?
- What is the best application for this battery?

Voltaiq Battery Intelligence Platform

CONTACT

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