



# voltaiq

## **Using Big Battery Data to Make Batteries that Work Better, Last Longer, and Function Reliably**

2016 NASA Aerospace Battery Workshop  
November 16, 2016

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CEO and Co-Founder

# Outline

- Battery challenges across industries
- How are companies doing it today?
- Data-driven product development
- Data-driven product development in action
- Deeper analytics enabled by data-driven product development



# Battery challenges across industries

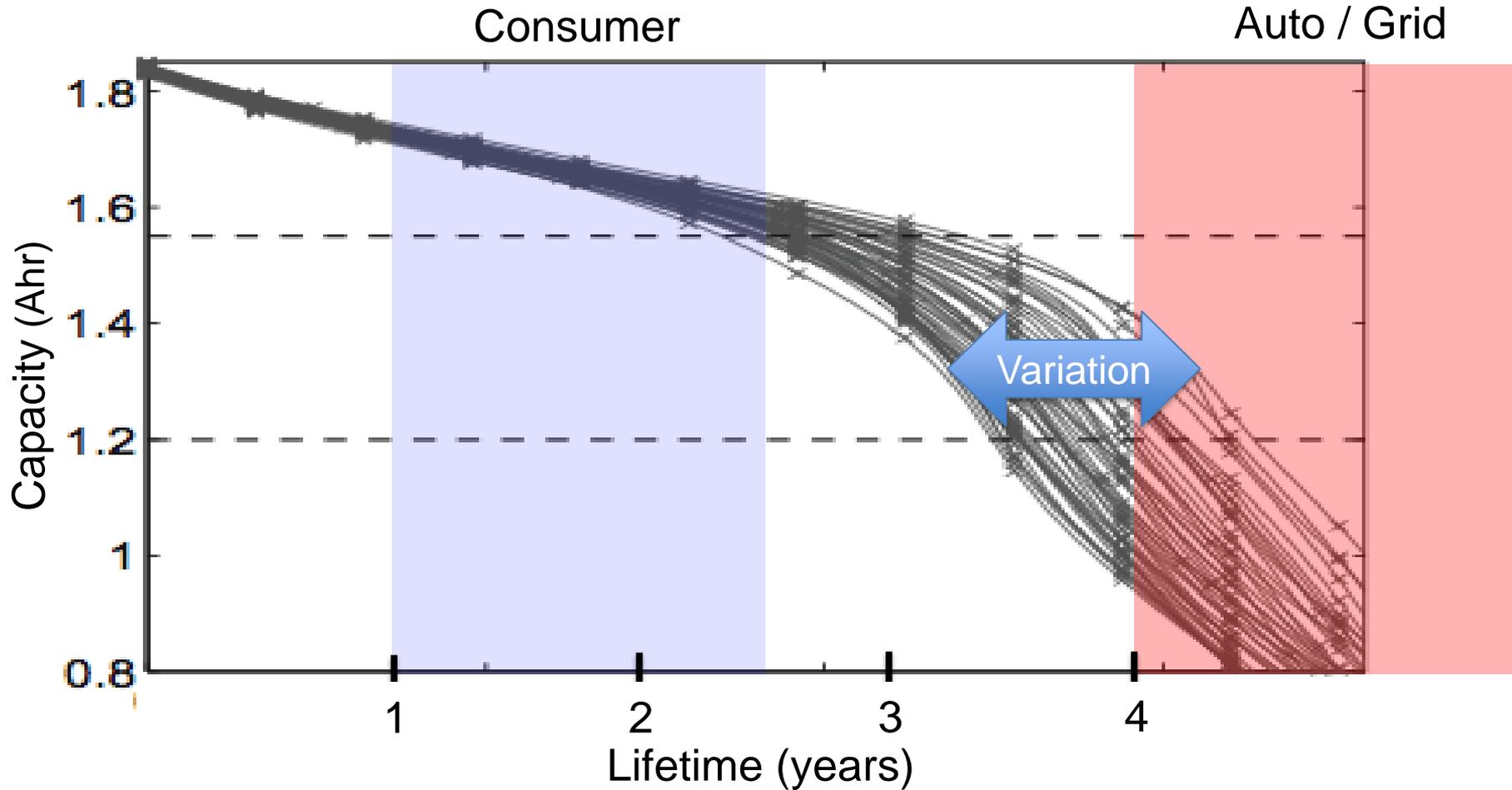
# Batteries are the bottleneck in nearly every application



- Resource intensive to test and develop
- Slow product development
- Incremental improvement
- Not enough time to test thoroughly for each application
- Inconsistent, unreliable in operation



# Longer warranties & expected battery lifetime



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

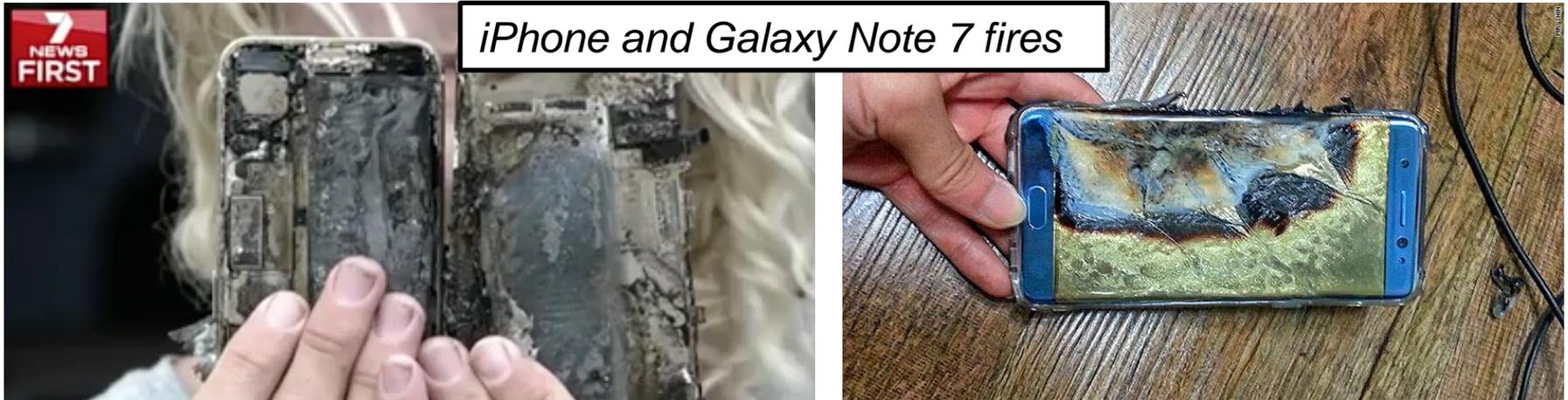
# Batteries are no longer removable



- You used to be able swap a bad battery.
- Many applications now have embedded batteries.
- When a battery fails today, you need to ship the entire device. Warranty claims are much more expensive.

# Higher energy densities, smaller / thinner form factors and fast charging

- Higher voltages and current densities put more stress on the battery
- Increased risk of lithium plating
- Swelling has become an issue, especially in small form factors
- Batteries continue to catch fire



# Consumer challenges

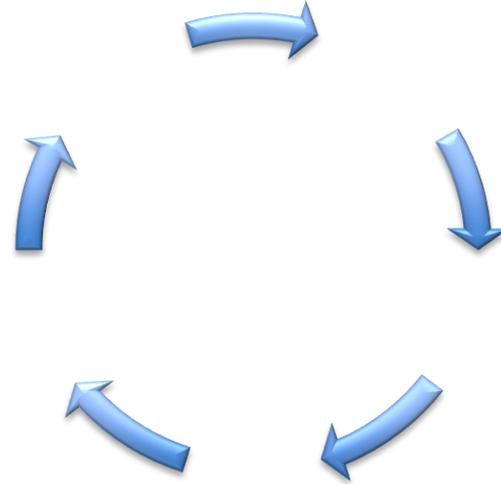
*When asked: “What new or improved smartphone feature are you most excited about?”*

*“**Improved battery life**” was the leading answer by a long shot.*

Fortune-SurveyMonkey study CES 2015

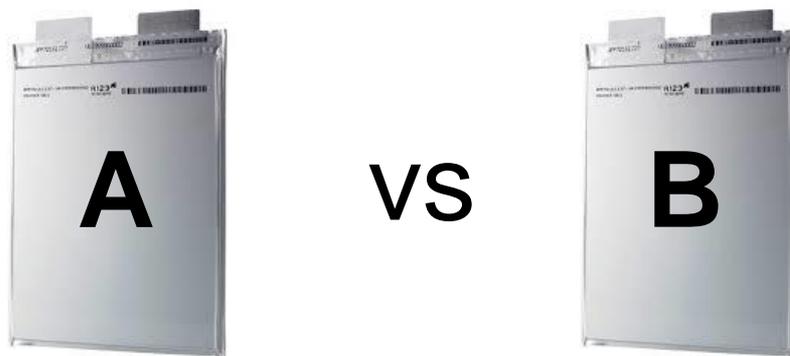
- Battery life is the single greatest source of consumer dissatisfaction
- User tastes are changing faster and faster

# Faster product development cycles



- Many industries are moving from biennial or yearly product cycles to 9 month or 6 month release cycles.
- This typically leaves only 2 to 4 months to evaluate batteries for an application.

# Choosing the right vendors



- It's almost impossible to compare vendors apples-to-apples using spec sheets alone.
- Reported 'cycle-life' uses a simplistic cycle that doesn't represent your application.
- Expected lifetime in application is impossible to determine without adequate testing, leading to warranty risks.

# Qualifying battery vendors better



- Many OEMs are sending people back and forth to Asia regularly to design and qualify custom batteries.
- QA data is being generated both in Asia at the battery vendors and in-house.



How are companies doing it today?

# All of these applications produce data



- In operation
- In research and development
- In integration testing
- In quality assurance

# Manual analysis with makeshift tools

- Highly paid engineers spend hours per day doing basic analysis, relying on outdated desktop software, inadequate spreadsheet-based processes, and expensive custom IT systems.
- Companies employ full-time technicians to process data, which can introduce errors and create a disconnect between the engineers making decisions and the insights they need to make them.



# Basic automation

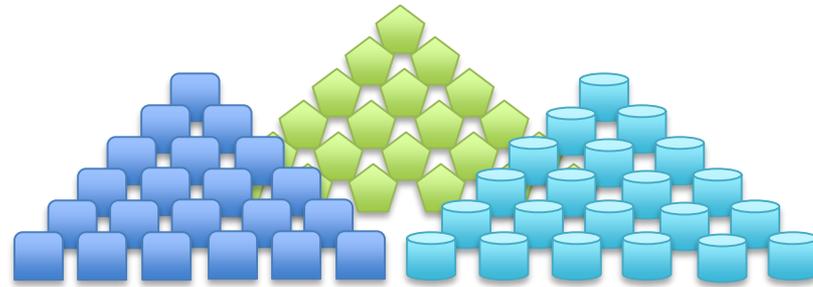
## Static reports or back to Excel



- Some companies have taken steps to automate analysis, creating some basic scripting or Excel macros. These often produce static reports or require further analysis in Excel.
- Still can't dig into the data easily or compare across your tests. Often leads to complacency, guesswork, and even less data analysis.

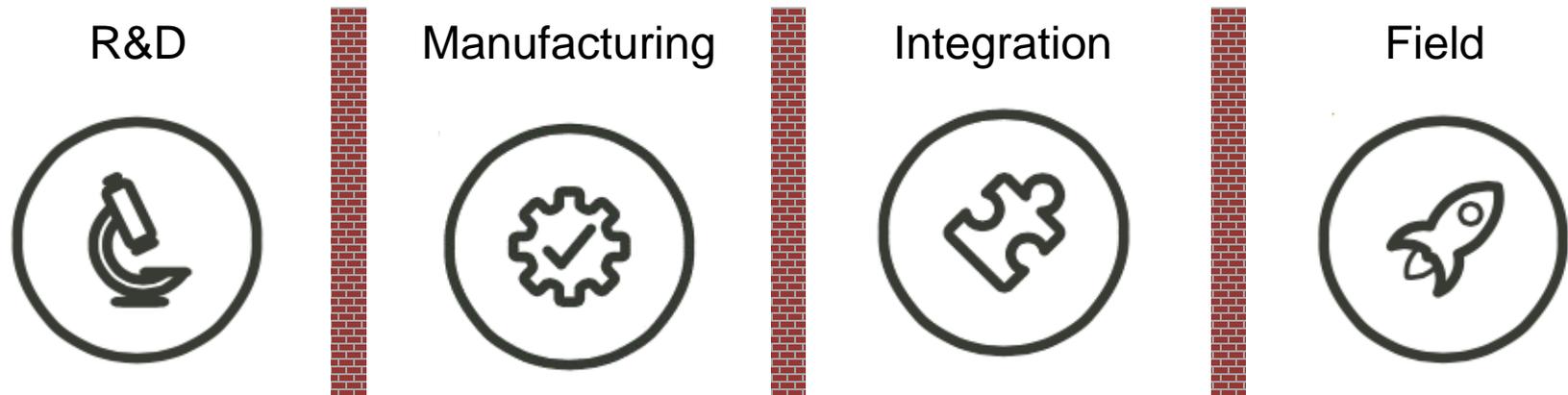
# Can't analyze more than a handful of batteries at a time

Too many files, too many formats



- Leads to empirical decisions made from small sub-segments of your body of data.

# Data isn't shared across the industry value chain



- Learning and the opportunity for improvement stops once it leaves your section of the organization.
- Data is starting to flow back, as warranty claims from long-life applications are sent back to battery vendors.

# Often just don't look at the data

*“Organizations **repeat up to 40%** of their experiments with resulting increased costs and longer development times.”*

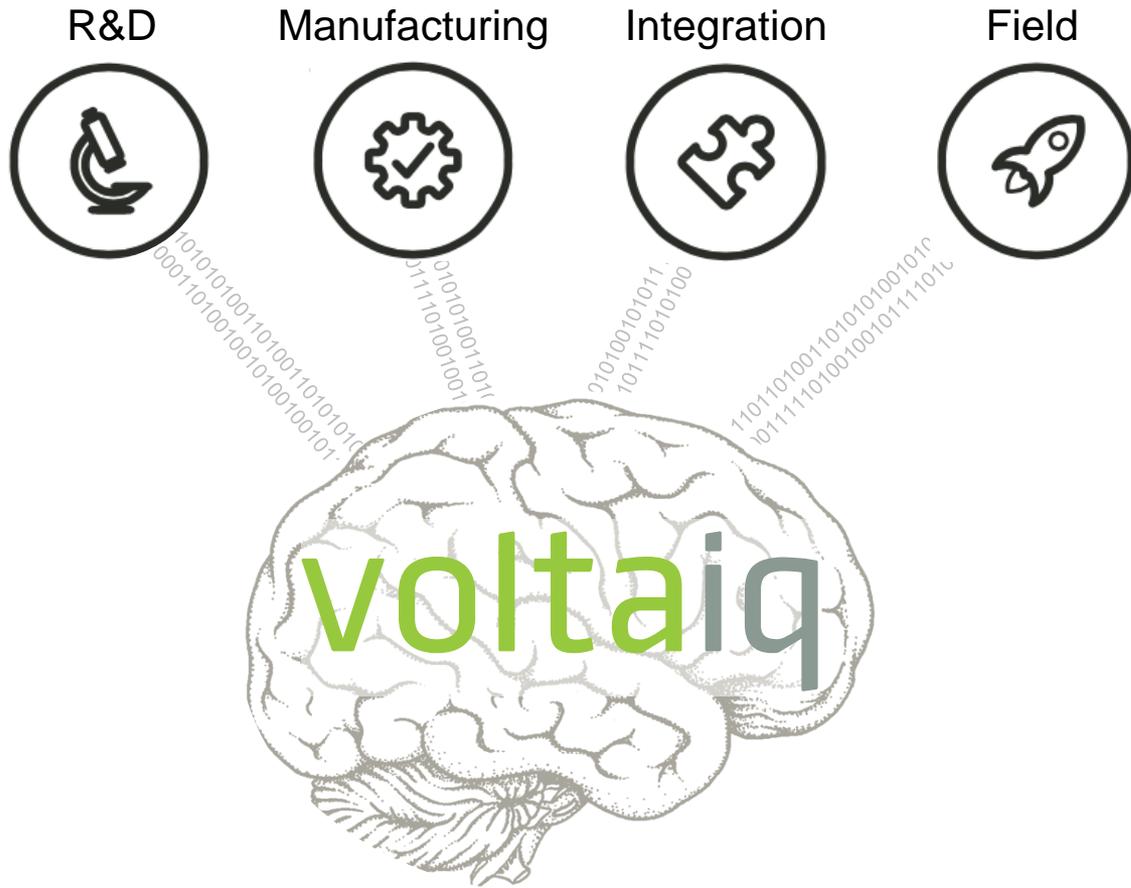
– IDC Insights

- Organizations are spending \$\$\$ to generate this data, but are only scratching the surface of its value, typically running only pass fail analysis or looking at top-level statistics.



# Data-driven product development

# Voltaiq is the enterprise platform for data-driven battery product development and optimization



- Get products to market faster using resources efficiently.
- Ship with confidence, ensuring safety and reliability in the field
- Turn battery performance into a competitive advantage

# Voltaiq: Access, Insight, Confidence

- **Access**

- One platform for all data, current and historical, across every facility
- Search, analyze, and collaborate in real time

- **Insight**

- Industry-leading algorithms and powerful analytical tools uncover trends hidden in your data
- Broad comparative analyses put results in context

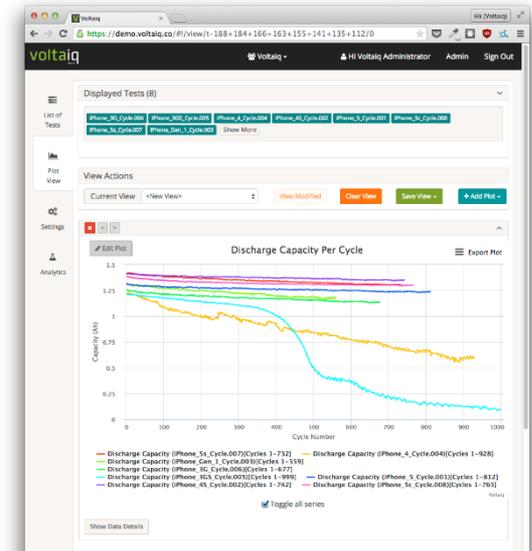
- **Confidence**

- Data-driven decision making for faster iteration
- Comprehensive analysis to mitigate battery product risks

# voltaiq Unified Data Pipeline



Data is instantly homogenized and centralized in Voltaiq



Any battery cycler or external data stream

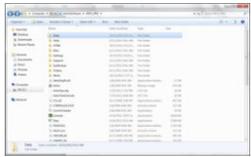
Quickly find, visualize and analyze your data



# Voltaiq gets battery powered products to market *faster*

## Typical workflow for data analysis

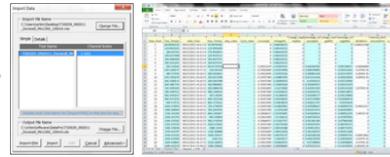
Find the files you need, from among thousands



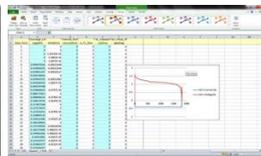
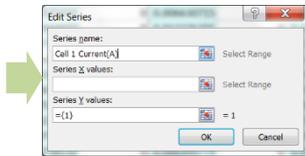
Transfer files to flash drive



Import the first data file into Excel



Plot the relevant data series, one by one



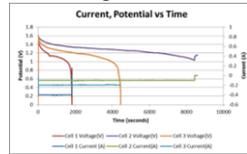
Repeat file import and plotting for each additional test



Modify plot options for each plot



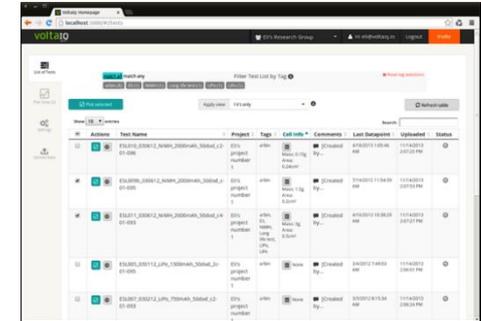
Export plot for presentation or emailing to colleagues



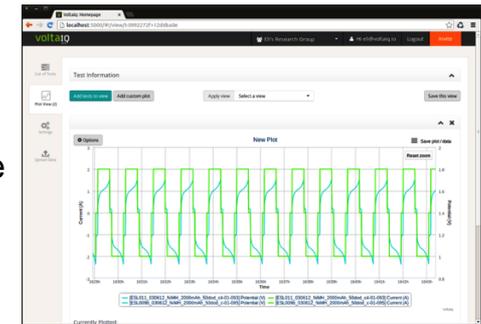
Repeat for each type of plot

## Voltaiq workflow

Select tests to compare



View plots in browser, share by URL



*Up to 20 hours of an engineer's time is returned to Engineering every week!  
Improve the pace of development and increase asset utilization - Saving \$.*

# Voltaiq uncovers actionable insights hidden in raw battery performance data

The screenshot displays the Voltaiq web application interface. At the top, there's a navigation bar with the Voltaiq logo, user name 'Hi Tal Sholklipper', and a 'Sign Out' button. Below the navigation bar, there are several utility buttons: 'Plot Selected', 'Analyze Selected', 'Edit Cell Info', 'Add Tests to Project', 'Tag Selected', and 'Comment Selected'. The main content area features a search bar, a 'Refresh Table' button, and a 'Clear All' button. A table lists various battery tests with the following columns: Actions, Test Name, Tags, Comments, Project, Cell Info, Cycles, Start Time, and Last Uploaded. The table contains 10 rows of test data.

Actions	Test Name	Tags	Comments	Project	Cell Info	Cycles	Start Time	Last Uploaded
	TS096TenergyStandardCycle-01-006	3	1	Tenergy Study		564	2015.08.03 09:12:39	2016.02.14 10:57:36
	TS103Tenergy05C02C42to34-01-012	4	1	Tenergy Study		537	2015.08.19 15:07:07	2016.02.14 10:56:56
	TS106Tenergy05C02C42to34-01-001	2	1	Tenergy Study		430	2015.09.21 08:34:35	2016.02.14 10:56:55
	TS105Tenergy05C02C42to34-01-024	3	1	Tenergy Study		531	2015.08.19 15:10:30	2016.02.14 10:56:55
	TS099TenergyStandardCycle-01-016	3	1	Tenergy Study		570	2015.08.03 09:18:31	2016.02.14 10:56:16
	TS087TenergyStandardCycleNoCV-01-018	3	1	Tenergy Study		918	2015.07.07 12:31:20	2016.02.14 10:56:16
	TS001_Arbin_LG_HG2_cycle-01-022	3	1	Arbin New Cyclers		135	2016.01.20 11:42:50	2016.02.14 10:56:16
	TS104Tenergy05C02C42to34-01-013	3	1	Tenergy Study		556	2015.08.19 15:09:56	2016.02.14 10:56:16
	TS003_Arbin_LG_HG2_cycle-01-017	3	1	Arbin New Cyclers		125	2016.01.22 10:05:51	2016.02.14 10:56:15

# Find your data quickly

Advanced Filtering: 'full text',  
or on any specific field

Status Indicator

The screenshot shows the Voltaiq dashboard interface. At the top, there's a search bar with the filter 'Projects: Alkaline' applied. A dropdown menu is open, showing options like 'Device Tags', 'Device Comments', 'Projects', 'Test Name', 'Device Name', 'Device Info', and 'Notebook'. The main table displays test results with columns for Actions, Device Name, Tests, Project, Device Info, Cycles, Tags, Comments, Created, and Last Updated. A status indicator (a battery icon) is visible in the 'Device Info' column for each row.

Actions	Device Name	Tests	Project	Device Info	Cycles	Tags	Comments	Created	Last Updated
[Icons]	Amazon_Alkaline_AA_100mA.005	[Icon]	Alkaline	[Icon]	1	[Icon]	[Icon]	2016.05.06 00:14:47	2016.05.06 00:14:47
[Icons]	Duracell_Pro_AA_100mA_N3.005	[Icon]	Alkaline	[Icon]	1	[Icon]	[Icon]	2016.05.06 00:14:00	2016.05.06 00:14:00
[Icons]	Maxell_AA_100mA_N3.005	[Icon]	Alkaline	[Icon]	1	[Icon]	[Icon]	2016.05.06 00:06:07	2016.05.06 00:06:07
[Icons]	Energizer_Ind_AA_250mA.002	[Icon]	Alkaline	[Icon]	1	[Icon]	[Icon]	2016.05.06 00:06:01	2016.05.06 00:06:01
[Icons]	Duracell_AA_500mA.001	[Icon]	Alkaline	[Icon]	1	[Icon]	[Icon]	2016.05.06 00:00:15	2016.05.06 00:00:15
[Icons]	Amazon_Alkaline_AA_500mA.005	[Icon]	Alkaline	[Icon]	1	[Icon]	[Icon]	2016.05.05 23:53:24	2016.05.05 23:53:24
[Icons]	Duracell_Pro_AA_100mA_N2.005	[Icon]	Alkaline	[Icon]	1	[Icon]	[Icon]	2016.05.05 23:52:09	2016.05.05 23:52:09
[Icons]	Amazon_Alkaline_AA_50mA.005	[Icon]	Alkaline	[Icon]	1	[Icon]	[Icon]	2016.05.05 23:51:57	2016.05.05 23:51:57
[Icons]	Duracell_AA_100mA_N3.007	[Icon]	Alkaline	[Icon]	1	[Icon]	[Icon]	2016.05.05 23:49:30	2016.05.05 23:49:30
[Icons]	Duracell_AA_250mA.001	[Icon]	Alkaline	[Icon]	1	[Icon]	[Icon]	2016.05.05 23:48:14	2016.05.05 23:48:14

Store multiple tests

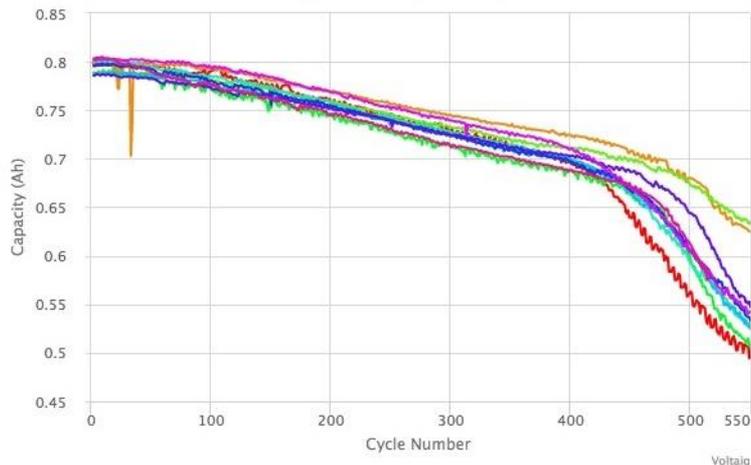
Projects

Meta-data

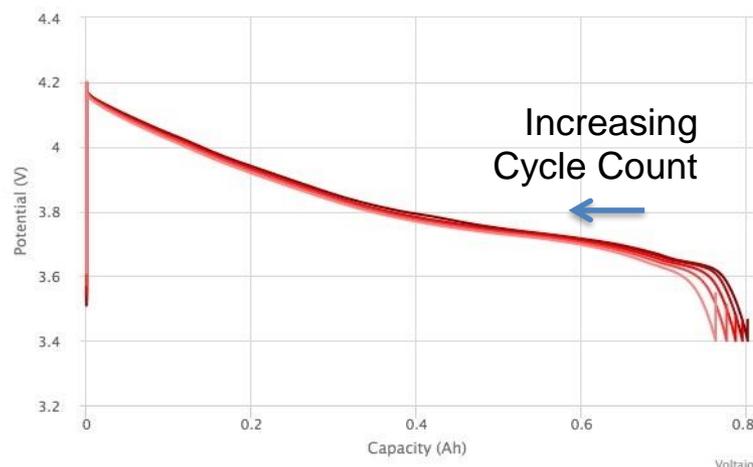
Custom Tags and Comments

# Fully customizable, reusable data views with interactive plots

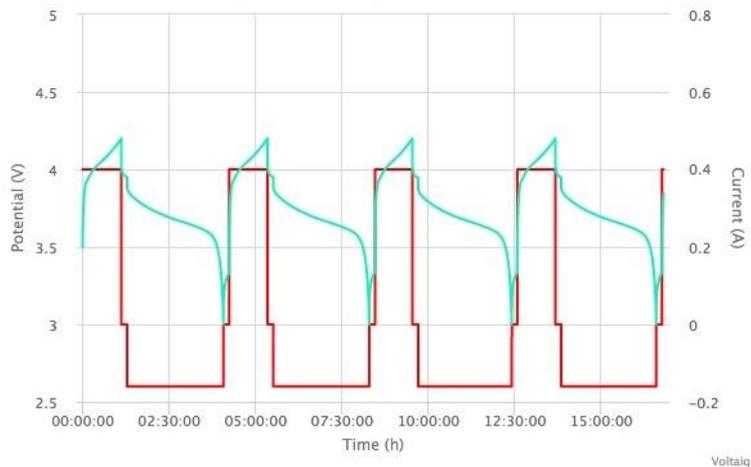
## Batch analysis



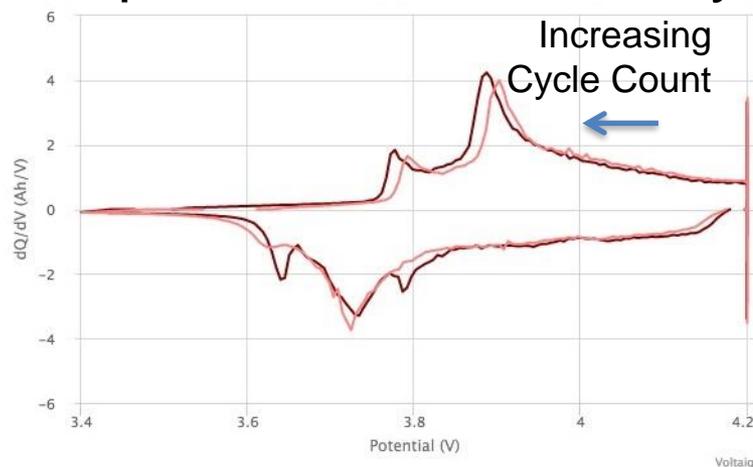
## Overlay cycles over time



## Zoom in on areas of interest



## Explore data in new ways



# Voltaiq configuration options

- Voltaiq Core
  - Automatically upload, process and normalize your data.
  - Quickly find and compare tests of interest.
  - Visualize, analyze and share your data in real-time.
- Voltaiq Analytics\*
  - Perform custom and batch analysis using Python scientific and numerical computing libraries.
- Voltaiq Notebook\*
  - Capture metadata around battery materials, processing, test conditions, and observations.
- Voltaiq Reports\*
  - Design and schedule regular reports and event-based alerts.

\* Optional

# Add-on Module: Voltaiq Analytics

- Python-based environment for advanced custom analysis, large-scale statistical studies and machine learning modeling
- Analyze any data in Voltaiq — live and historical
- Generate printed data, figures, and data files

The screenshot displays the Voltaiq Analytics interface. On the left, the 'Input Script (read only)' pane shows a Python script for data analysis and visualization. The script processes a list of test results, extracts discharge capacity values, and generates a histogram. On the right, the 'Output Results' pane shows a histogram titled 'Histogram of Tests' with a count on the y-axis and 'Discharge Capacity Cycle 100 in Ah' on the x-axis. Below the histogram, summary statistics are provided: Number of Tests: 21, Mean: 0.6111Ah, Median: 0.6823Ah, Range: 0.4678, Min: 0.3332Ah, Max: 0.801Ah. The interface also includes a navigation bar at the top with 'Logout' and 'Invite' buttons, and a footer with 'Execute Script' and 'Clear Results' buttons.

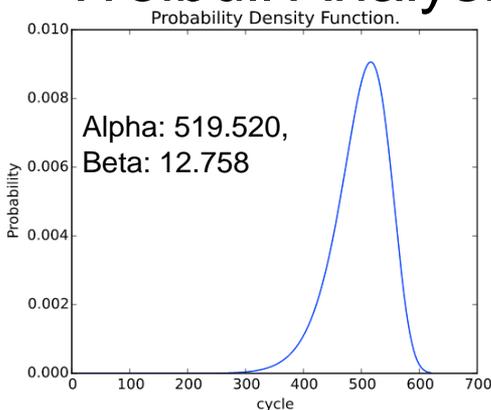
```
26 data = np.array([
27     [r['cycle'], r['discharge_capacity']]
28     for r in result])
29
30 # msg = test['name'] + ': Capacity at Cycle ' + repr(c
31 # PRINT(msg)
32
33 capacity_array = np.hstack((capacity_array, data[[cycle
34
35 # PRINT(capacity_array)
36
37 else:
38 msg = test['name'] + ' does not contain cycle ' + repr(c
39 # PRINT(msg)
40
41 # PRINT (capacity_array)
42
43 fig = plt.figure()
44
45 ax = fig.add_subplot(111)
46 ax.set_title('Histogram of Tests', fontsize=14, fontweight='bol
47 text = 'Discharge Capacity Cycle ' + repr(cycle_number) + ' in A
48 ax.set_xlabel(text, fontsize=10)
49 ax.set_ylabel('Count', fontsize=10)
50
51 ax.hist(capacity_array, color='blue')
52 PLOT()
53
54 msg = 'Number of Tests: ' + repr(capacity_array.size) + '\nMean
55 PRINT(msg)
56
57 PRINT('All done!')
```

Number of Tests: 21  
Mean: 0.6111Ah, Median: 0.6823Ah  
Range: 0.4678, Min: 0.3332Ah, Max: 0.801Ah

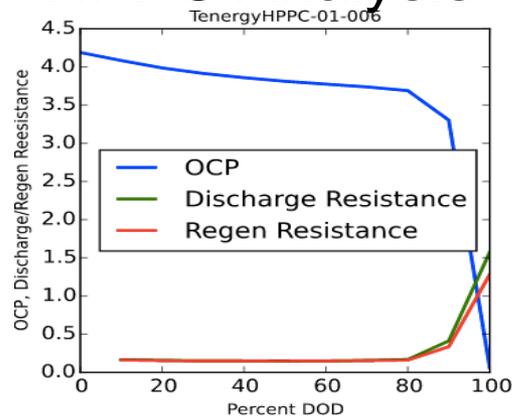
# Example Voltaiq Analytics use cases

- Pass/fail automation
- Reporting automation
- Specialty analysis (HPPC, Capacitor, etc.)
- Statistics for production, life prediction, etc.

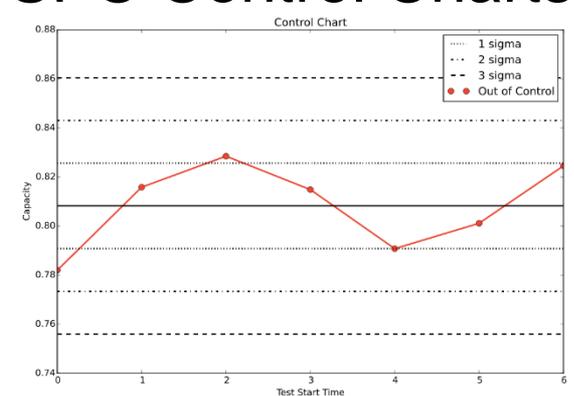
## Weibull Analysis



## HPPC Analysis



## SPC Control Charts



# Add-on Module: Voltaiq Notebook

- Integrated data management with fully customizable notebook templates: Capture metadata around battery materials, processing, test conditions, and observations.
- Associate Notebook data directly with performance data, analyze in interactive plots in Voltaiq Core, custom analytics in Voltaiq Analytics.
- Full version control and traceability.

Full customization based on fields you need to track

The screenshot displays the 'Notebook' interface. The 'Build Information' section includes fields for 'Manufacture Date' (2014-08-10), 'Rated Capacity' (3.62 Ah), 'Initial IR' (165.69 mΩ), 'Cathode Composition' (LTO), 'Anode Composition' (C), and 'Separators' (Dreamweaver Silver). The 'Swelling Measurements' section is a table with columns for 'Measurement Date', 'Measurement Cycle #', 'Mass', 'Height', and 'Diameter'. Two rows of data are visible, with a '+' icon at the bottom left of the table indicating that more measurements can be added. At the bottom right of the interface are 'Cancel', 'Apply', and 'Save' buttons.

Measurement Date	Measurement Cycle #	Mass	Height	Diameter
2016-01-01	72	20.06 g	48.5 mm	14.5 mm
2016-01-21	97	20.06 g	48.5 mm	14.6 mm

Collect measurements over time

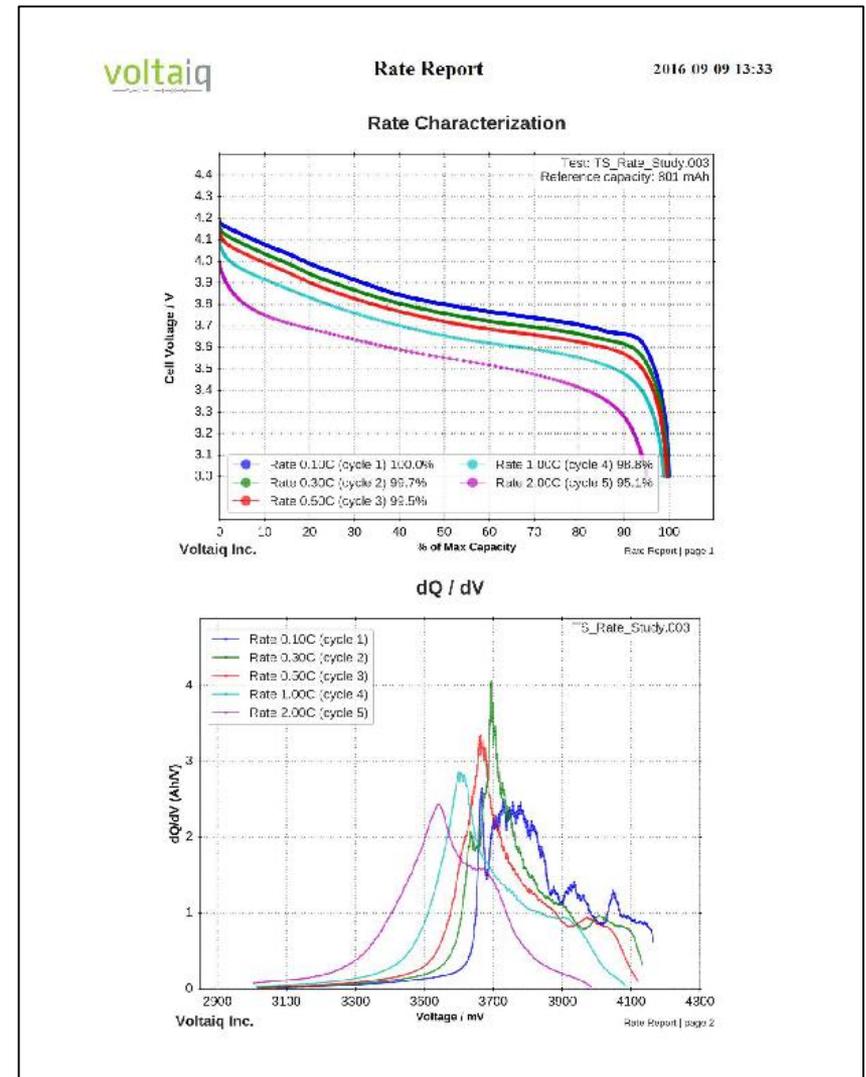
# Example Voltaiq Notebook use cases

- In R&D to optimize device composition and build faster.
- Integrate with existing systems
  - Manufacturing execution system (MES)
  - Enterprise resource planning (ERP)
- Track measurements and observations over time.
  - Changes in weights and dimensions.



# Add-on Module: Voltaiq Reports

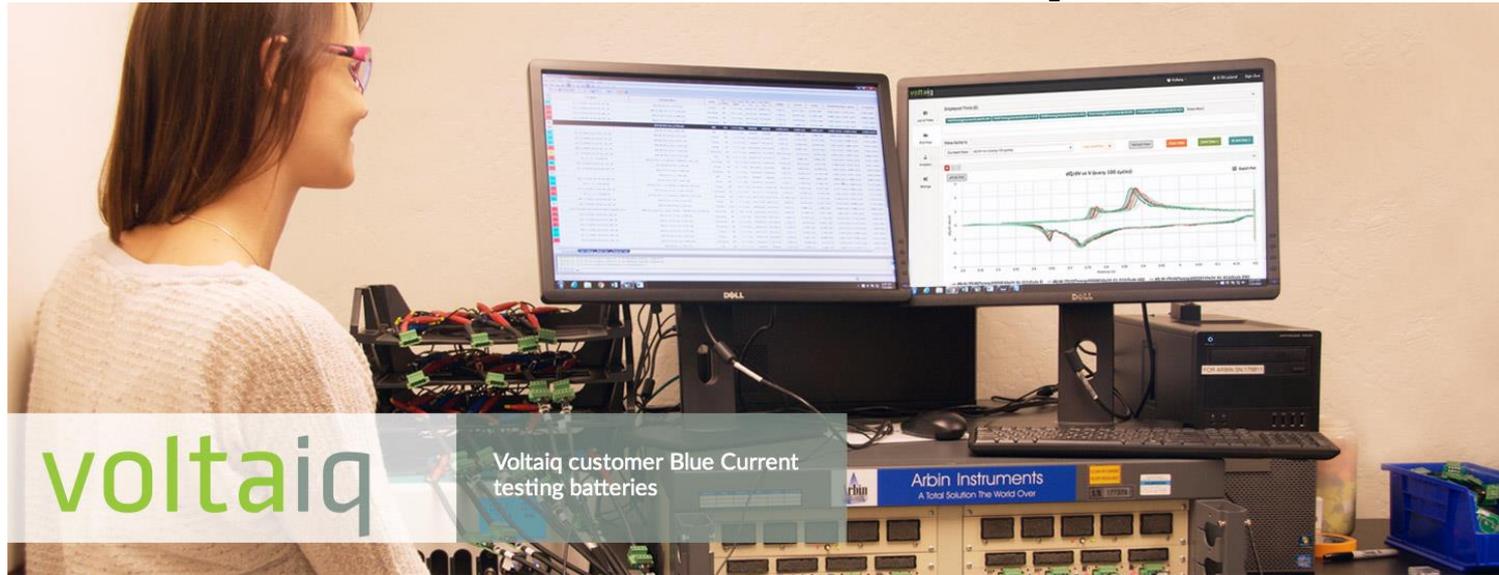
- Schedule reports emailed directly to your inbox on a regular or event-driven basis.
- Full customizability.
- The Voltaiq ‘virtual technician’





# Data-driven product development in action

# Research and Development



- Customers analyze new systems in real-time as tests are running, and learn much more about them.
- Engineering teams iterate faster and accelerate development cycles dramatically.
- Equipment utilization improves by spotting idle channels and channels that can be freed up.

# Product integration and vendor selection

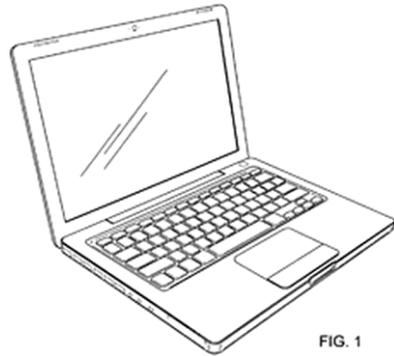
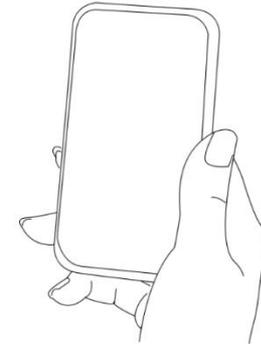
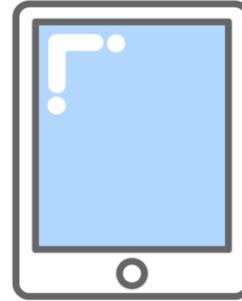


FIG. 1



- Work with OEMs to better design and optimize batteries for each application.
- Ensure that batteries will last long enough in application, minimizing warranty risks.
- Directly tie vendor testing in Asia to testing performed in-house, ensuring reliability.

# Quality assurance



- Automate pass / fail reporting, including deeper analysis beyond basic statistics.
- More importantly, when something is amiss customers can quickly dig in and determine the root cause with real-time interactive analysis.

# Field Operations

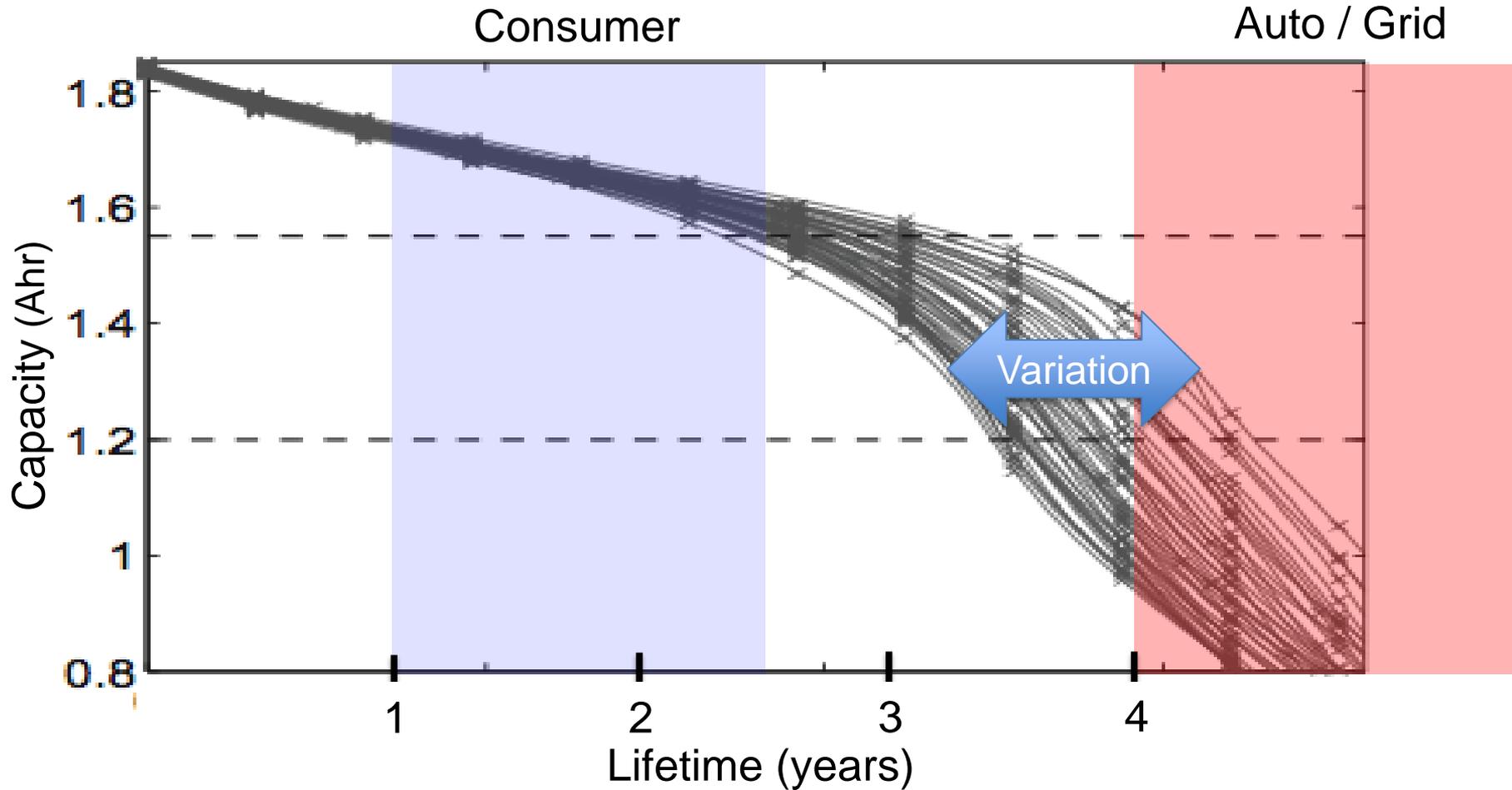


- Compare system performance across market segments and applications.
- Identify and troubleshoot poorly performing systems.
- Predictive analytics for battery lifetime and failure: Assess SOH and remaining service life; schedule maintenance, replacement; estimate warranty liability.



# Deeper analytics enabled by data-driven product development

# Longer warranties have created new challenges



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

# Getting more from your raw data: Capacity isn't enough

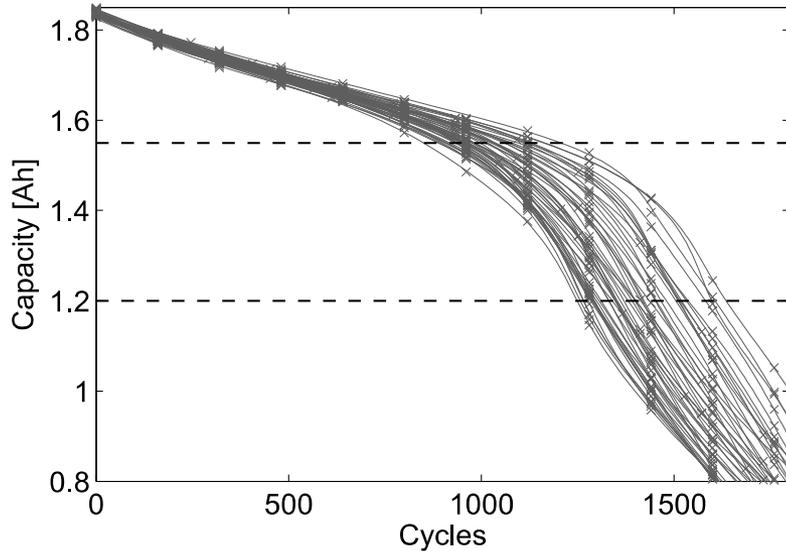


Fig. 6. Different aging trends from 48 equal cells under same aging conditions and profiles.

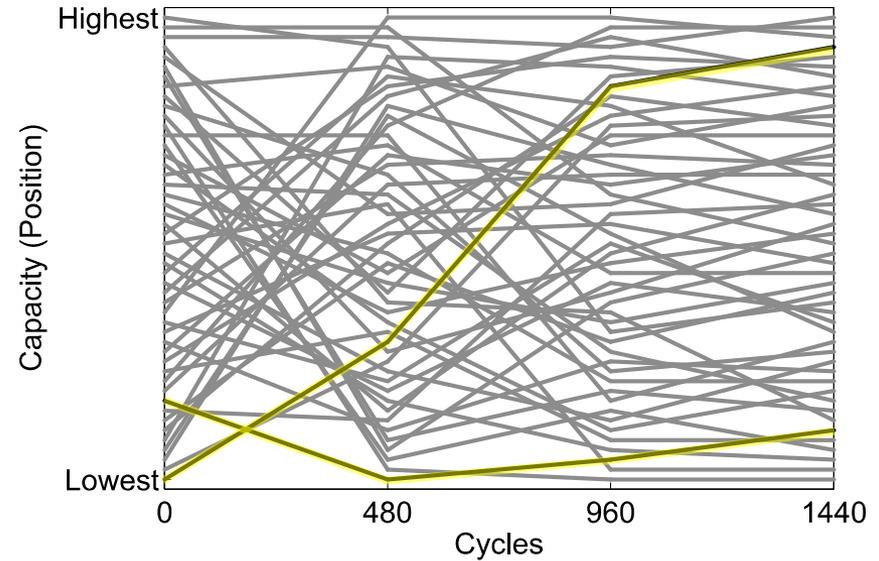


Fig. 7. Development of the position of the 48 cells within the sorted capacity at four cycle lifetimes.

*Minimal correlation between capacity early and late in the life cycle*

# Need to probe deeper into the data

*Identify signatures of primary degradation mechanisms*

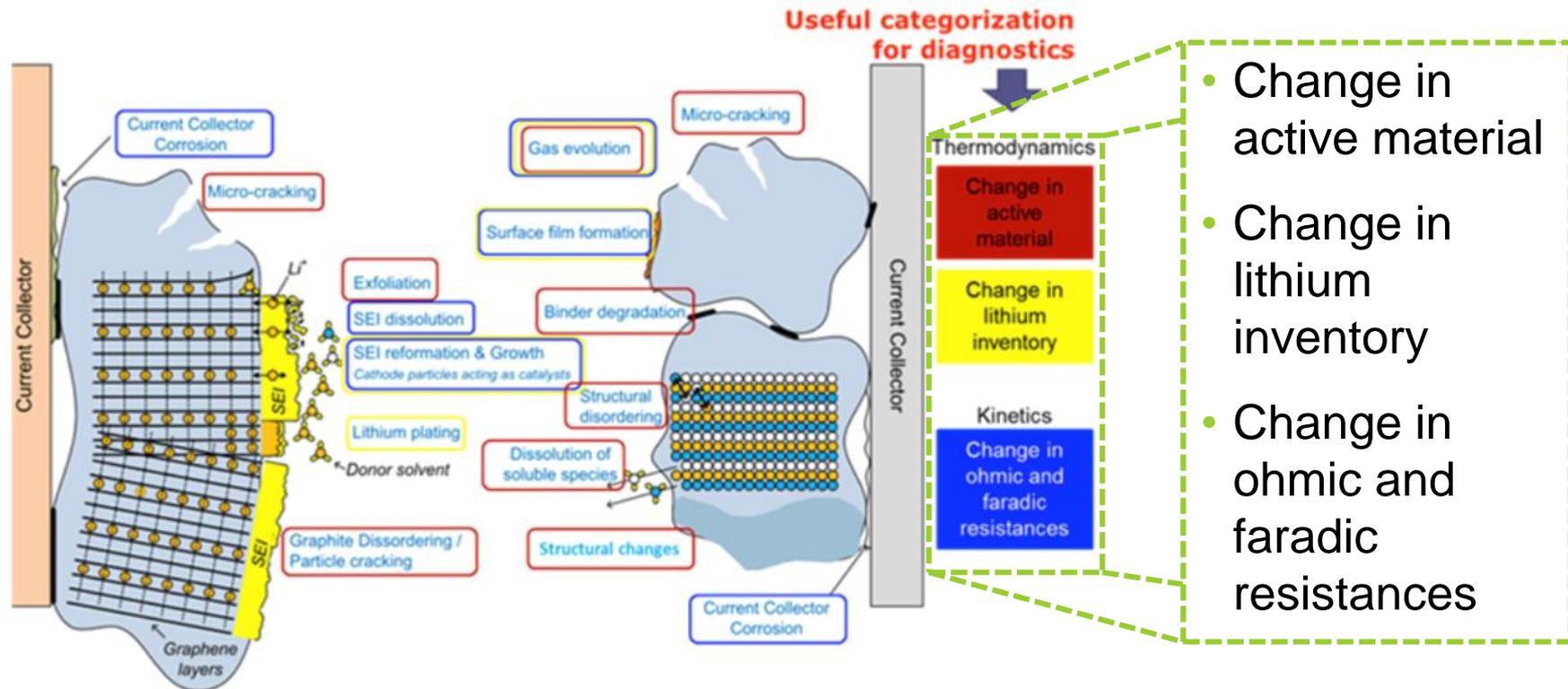
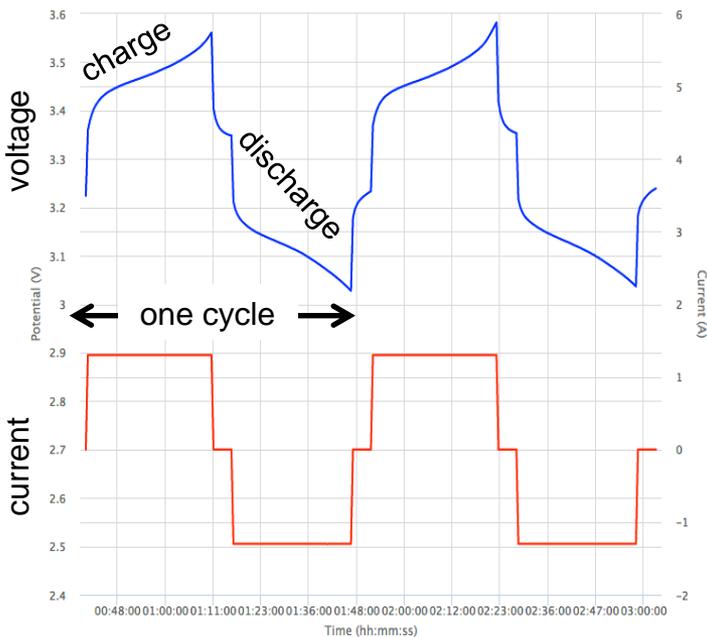


Fig. 1 Schematic of possible degradation processes in a Li-ion battery. Adapted with permission from [1].

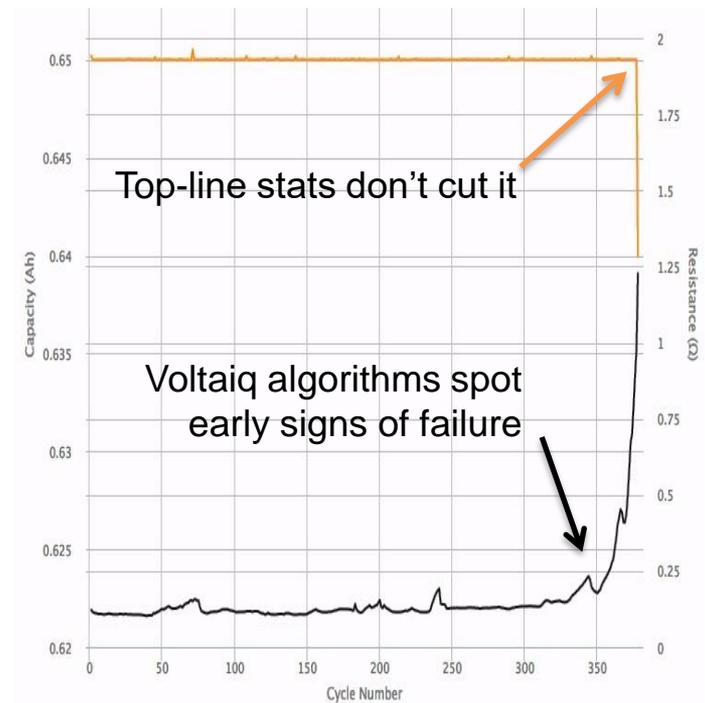
# Dig deeper and extract key diagnostic information from raw time series data

From raw time-series current and voltage...



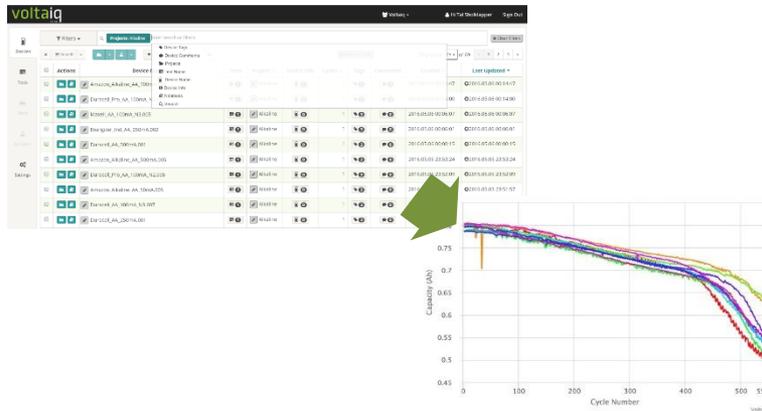
**voltaiq**  
proprietary  
analytics

Predict failure

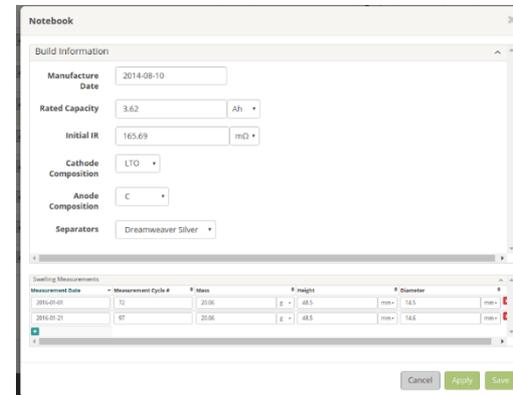


# Use the Voltaiq Battery Intelligence Platform to drive product development

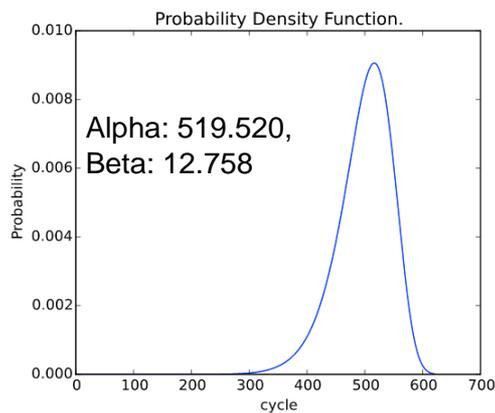
- Voltaiq Core



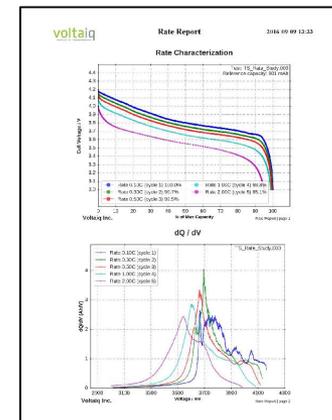
- Voltaiq Notebook



- Voltaiq Analytics



- Voltaiq Reports



# Get Products to Market **Faster** at a **Lower Cost** and Ensure **Safety** and **Reliability**

- Complete projects significantly faster (10x or more) by leveraging existing research and IP, and automating routine data gathering and analysis.
- Uncover hidden knowledge by quickly aggregating and processing massive volumes of data from different operating units.
- Enable collaboration across employees, partners, departments and throughout the organization.
- Improve decision making with better, faster results through real-time, interactive reporting.
- Reduce the risk from product failure by 80%, potentially saving billions of dollars.
- Reduce total cost of ownership (TCO) through a common and consistent approach to IT services.

# Thank you!

To learn more please visit our website

[www.voltaiq.com](http://www.voltaiq.com)

or contact us at

[info@voltaiq.com](mailto:info@voltaiq.com)

(646) 586-3062