

# AMPED

## Thinking outside the cell for better batteries

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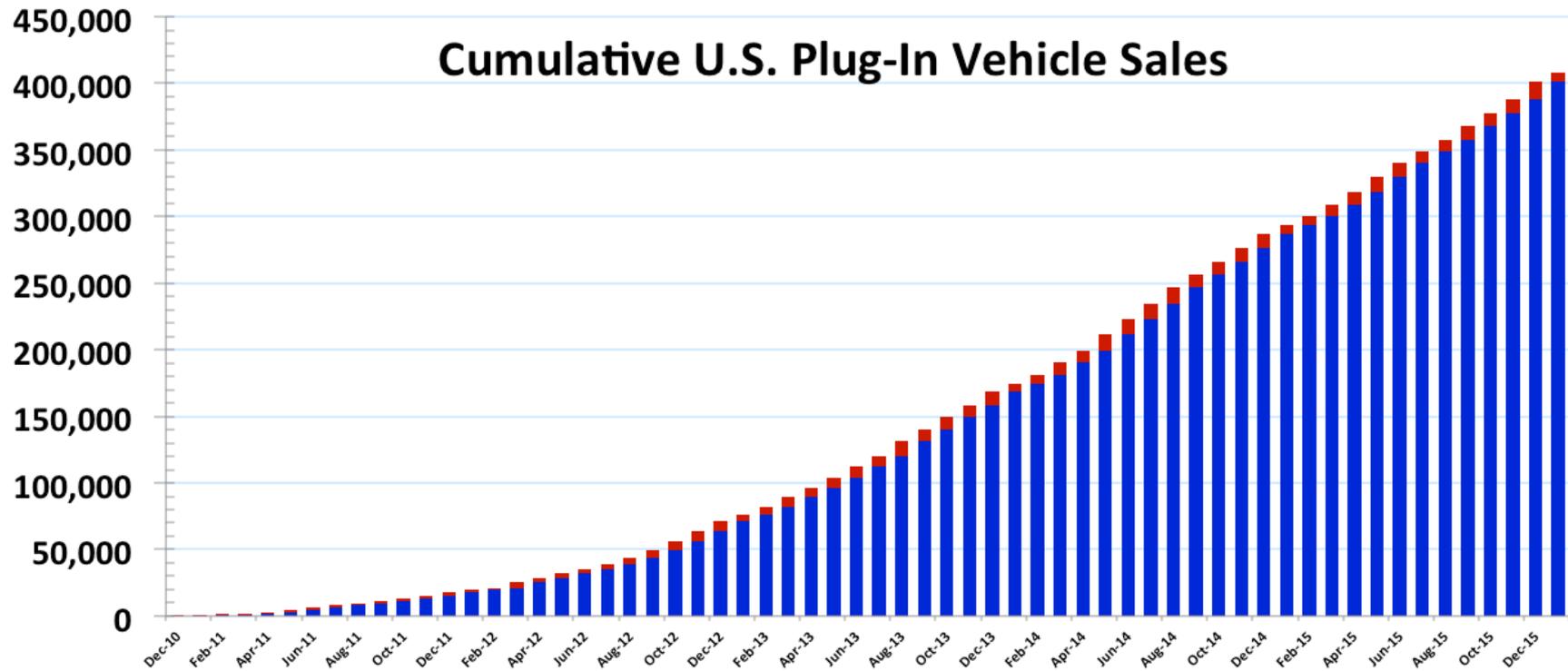
# The Lithium ion battery is a miracle

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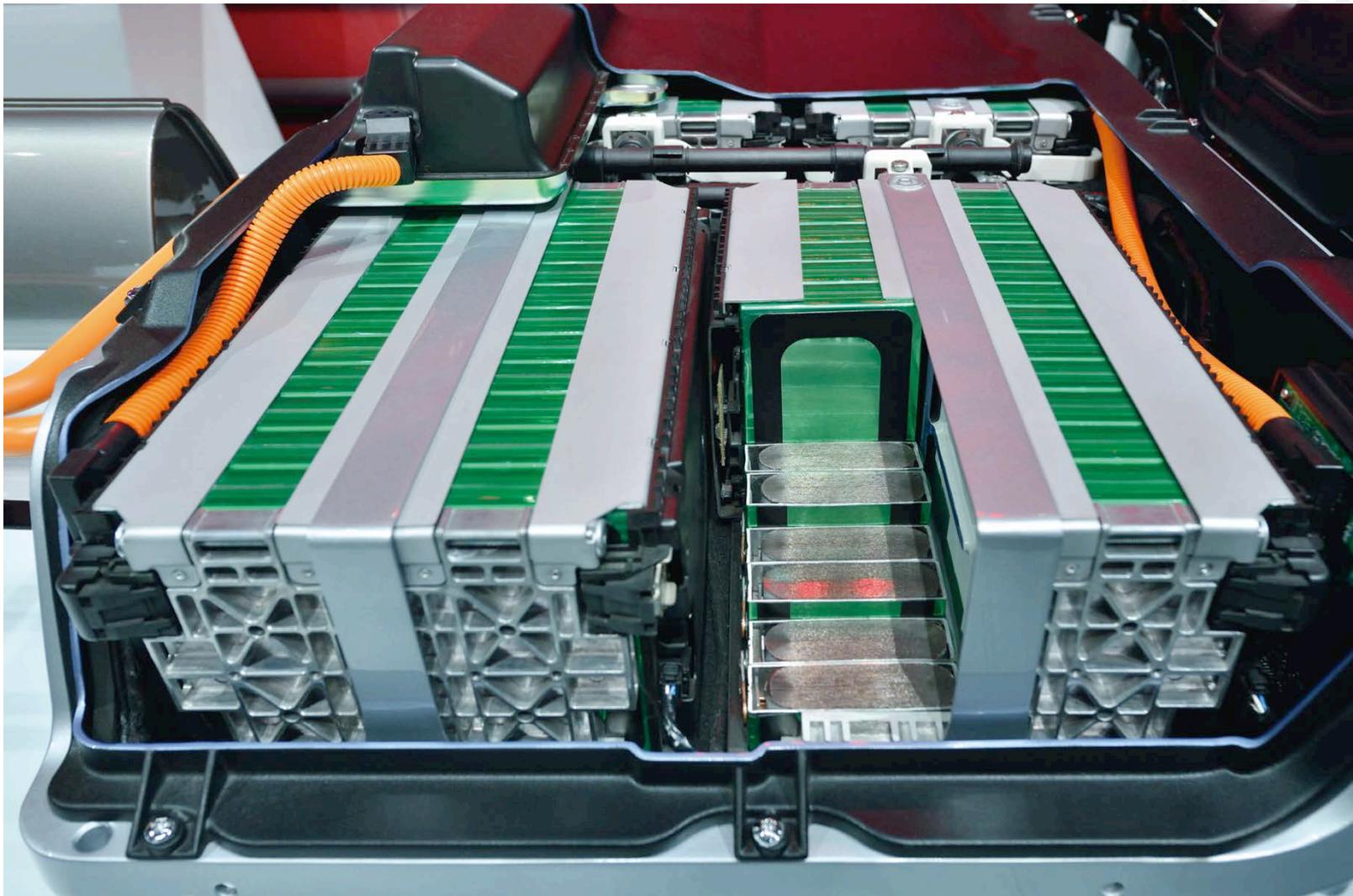
<https://www.eleafus.com/sony-vtc4-2100mah-rechargeable-high-drain-battery.html>

# The Lithium ion battery is a miracle

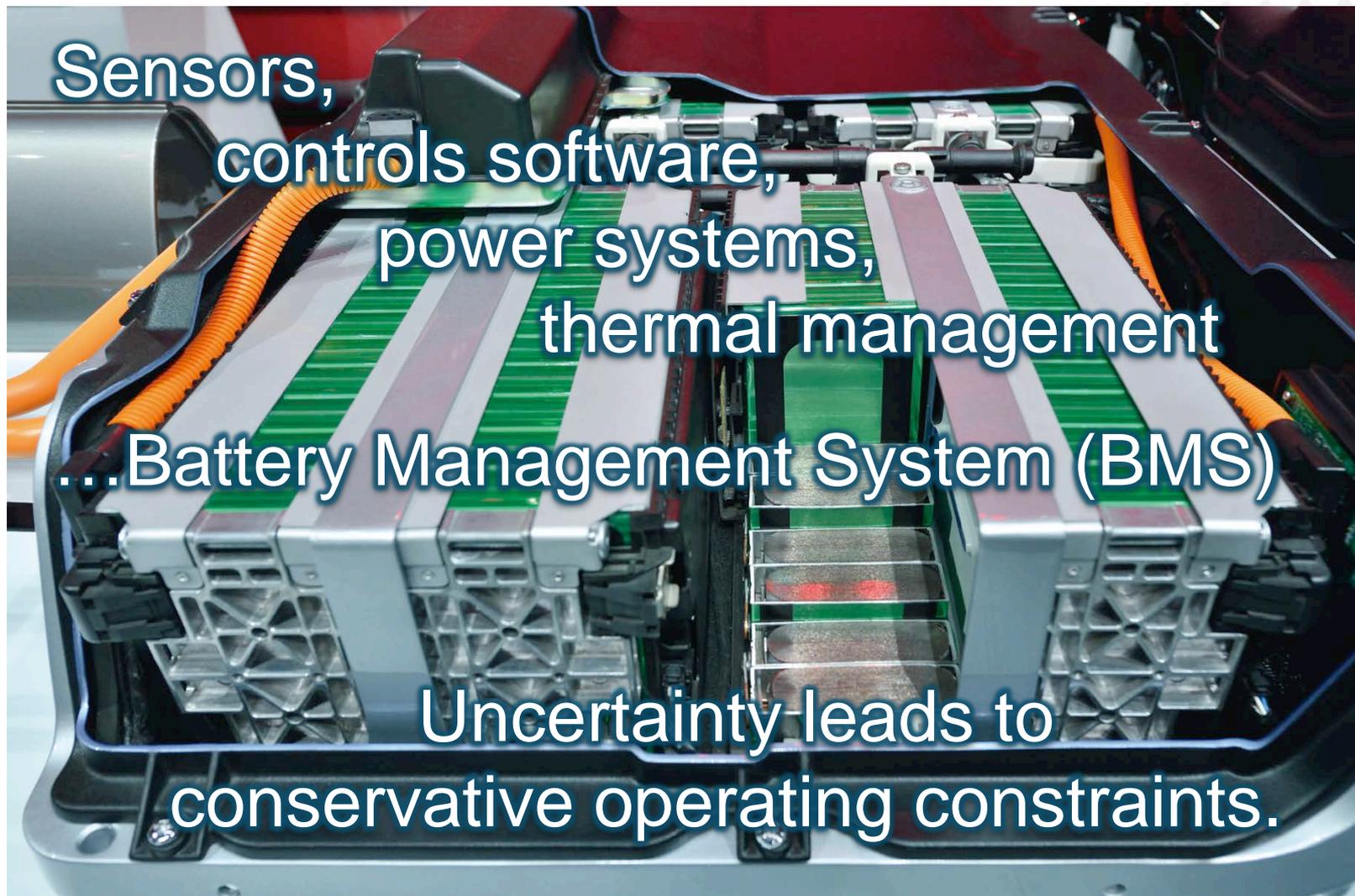


Source: Argonne National Lab  
[http://www.transportation.anl.gov/technology\\_analysis/edrive\\_vehicle\\_monthly\\_sales.html](http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html)

**But a battery is more than cells. It is a system.**



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Sensors,  
controls software,  
power systems,  
thermal management  
...Battery Management System (BMS)

Uncertainty leads to  
conservative operating constraints.

# AMPED built better *systems* for better batteries

## 1. Direct Sensing

- Internal cell temperature
- Intercalation strain
- Optical sensing
- Gas signatures



## 2. Modeling & Controls

- Real-time physical state estimation
- Adaptive degradation models



## 3. Flexible Power Systems

- Cost effective cell-level power management
- Flexible power architectures
- Wireless communications
- Intra-cell thermal management



## 4. Diagnostics & Prognostics

- High-precision coulombic efficiency
- Non-destructive acoustic inspection



# AMPED built better *systems* for better batteries

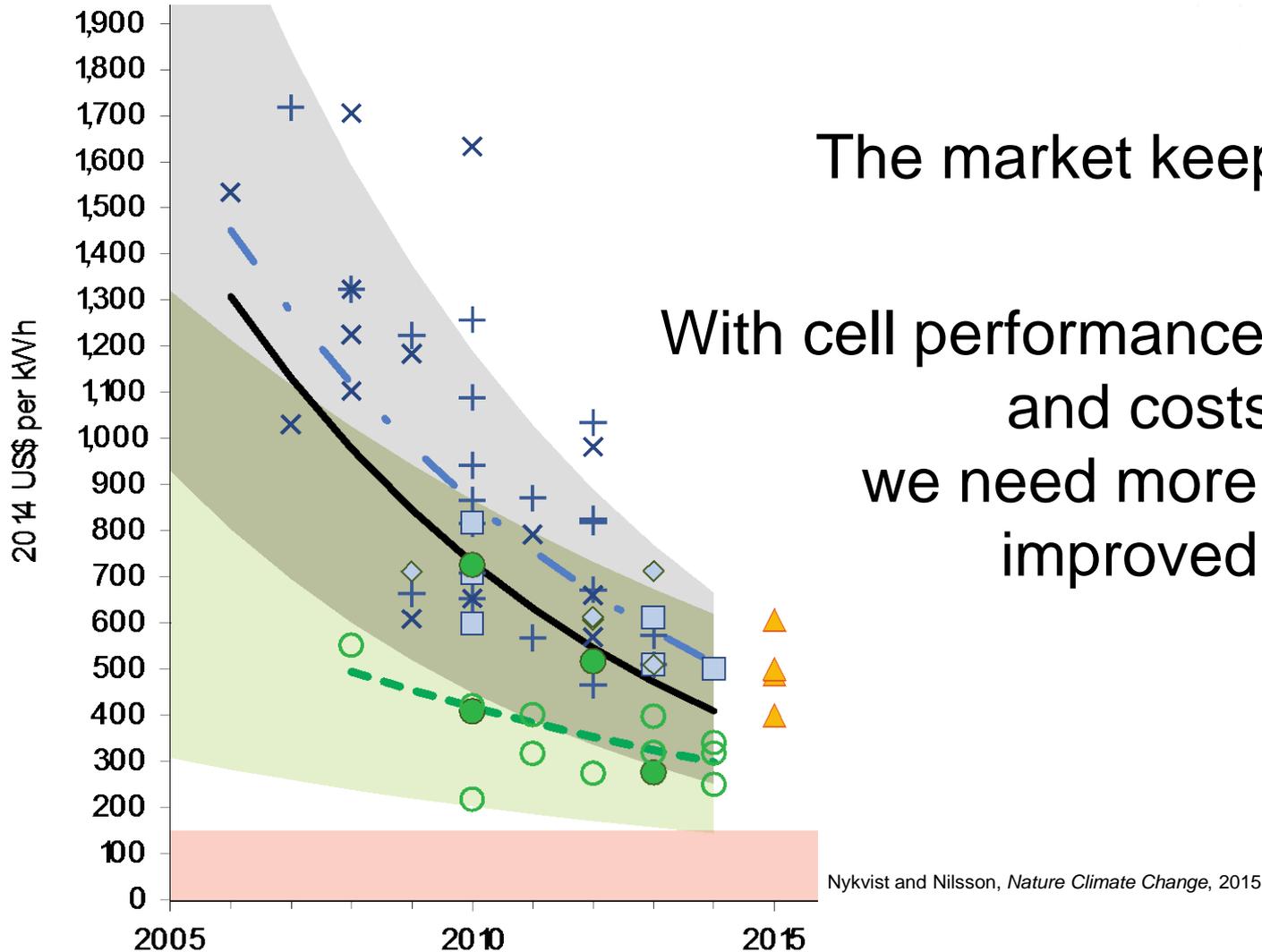
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*Increased cell utilization by 20% (and more)*

*Doubled charging rate*

*Demonstrated ability to monitor, track, and predict  
battery state of health*

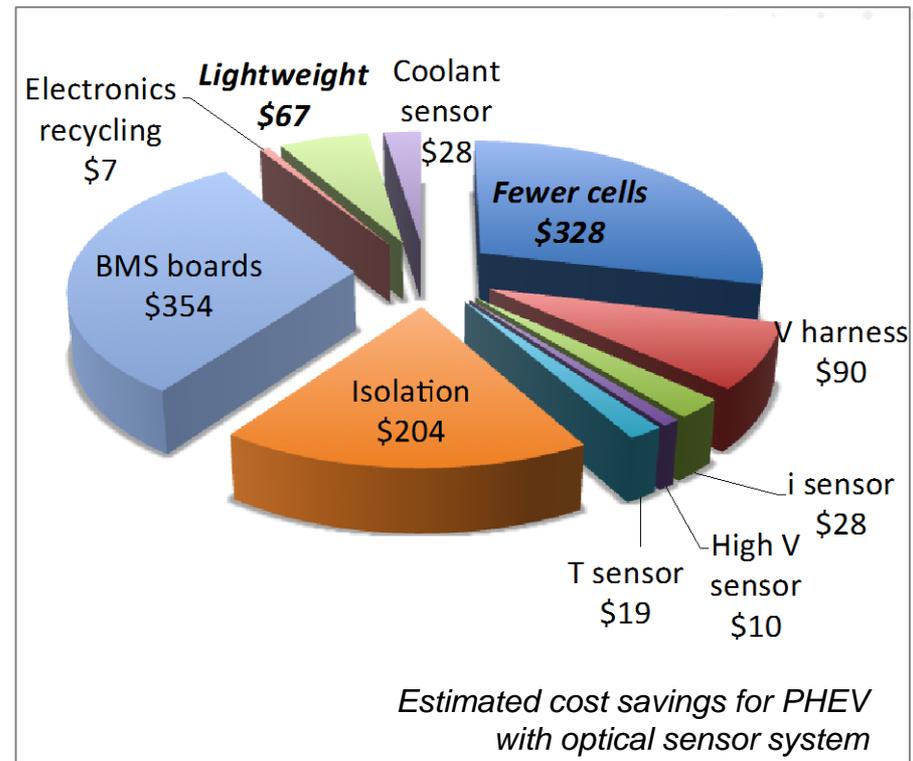
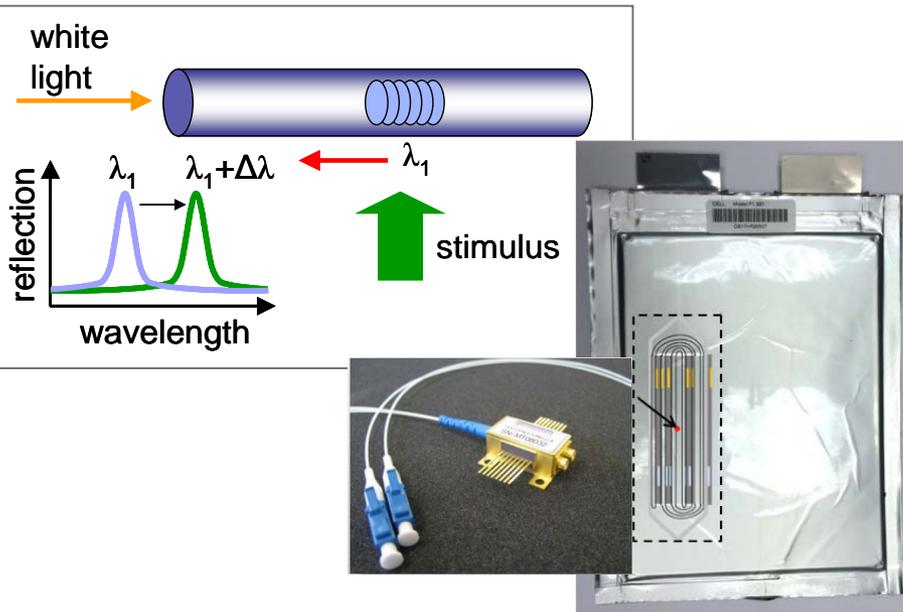
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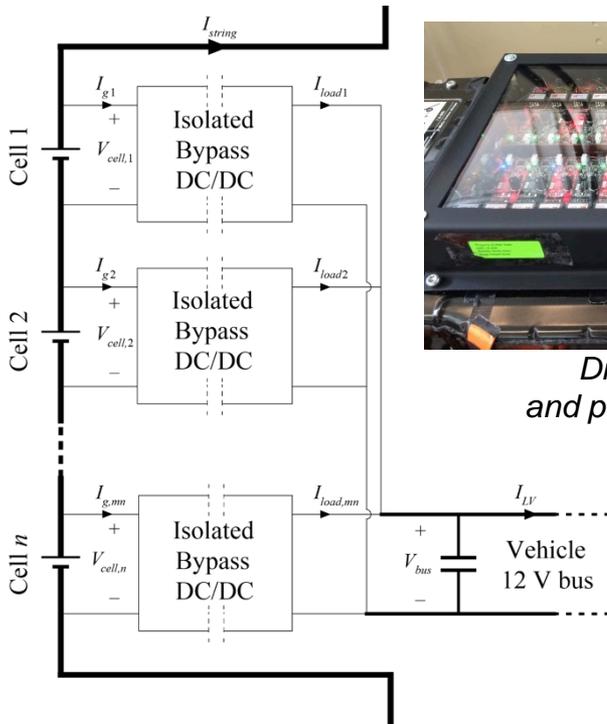
Optical sensors help reduce pack size,  
but *electrical isolation is worth even more.*

**parc**  
A Xerox Company

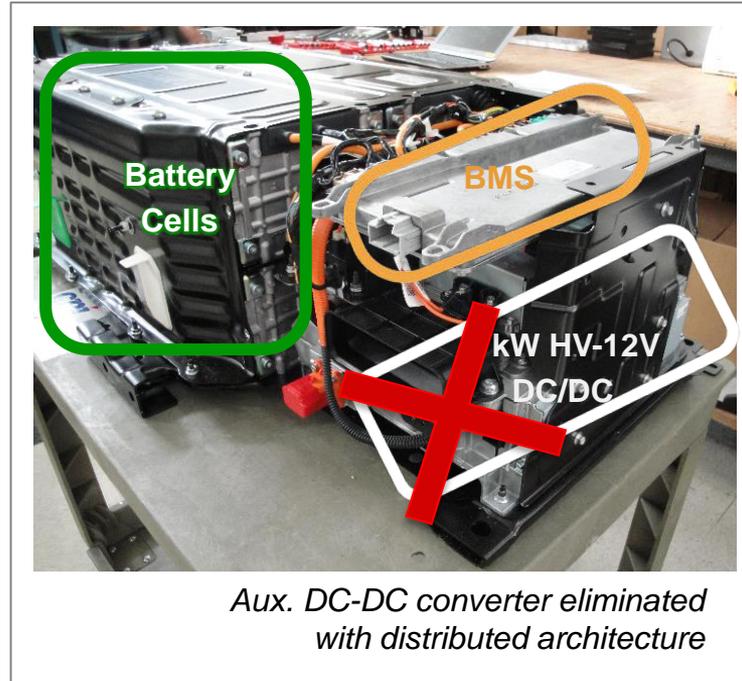


# What did we learn along the way?

Distributed power electronics enables cell-level control, but also *eliminates larger, more expensive components in the vehicle*

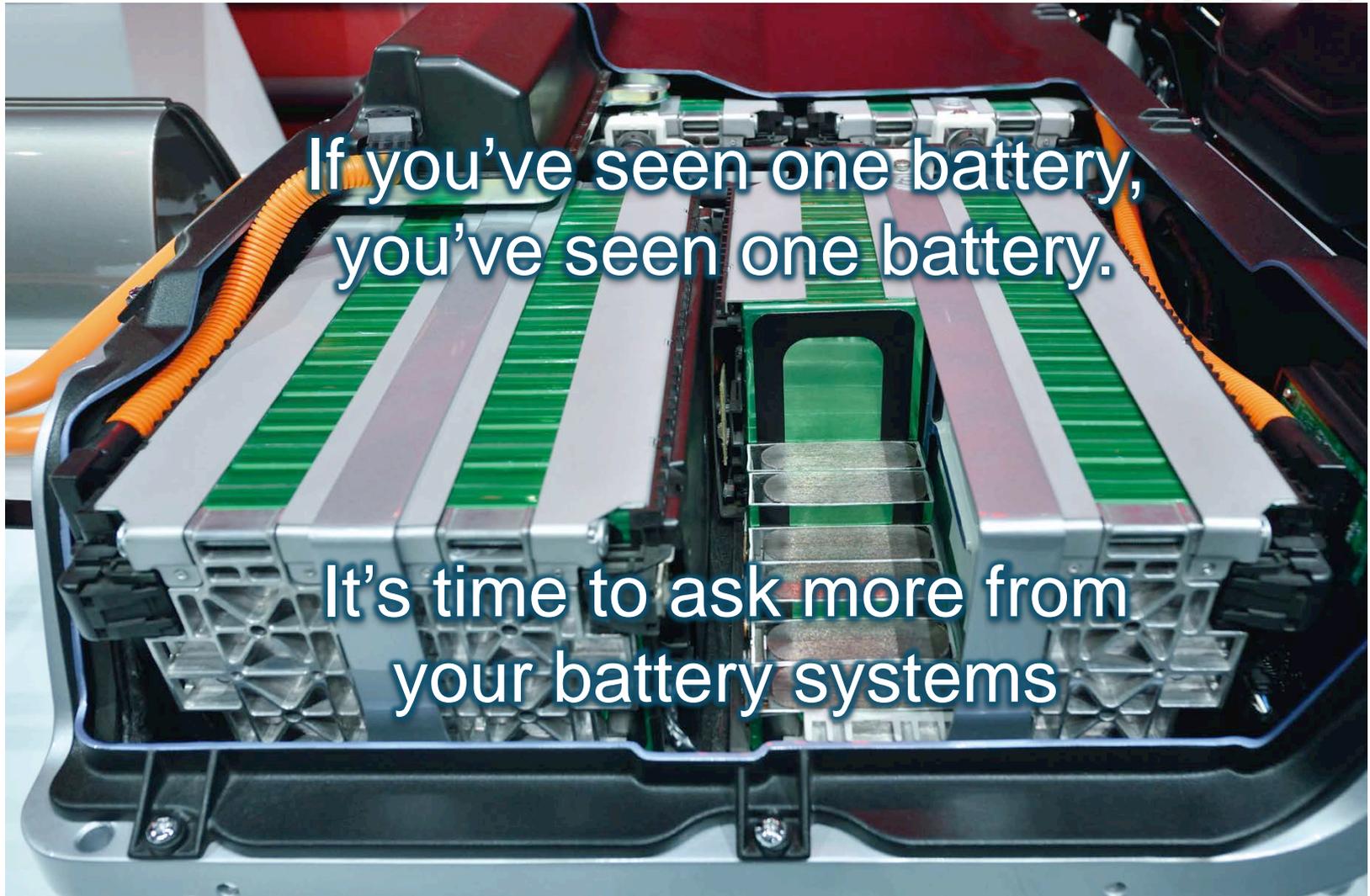


*Distributed DC-DC architecture and prototype on Ford C-max pack*



*Aux. DC-DC converter eliminated with distributed architecture*

# What comes next?



If you've seen one battery,  
you've seen one battery.

It's time to ask more from  
your battery systems



**Battelle**  
The Business of Innovation



**BOSCH**  
Invented for life



UC San Diego

University of Colorado  
Boulder



EaglePicher™  
Technologies,  
Yardney



**EATON**  
Powering Business Worldwide



**FARASIS**

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NATIONAL ACCELERATOR LABORATORY



Sandia  
National  
Laboratories



**GE**  
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MATERIALS

**NREL**  
National Renewable  
Energy Laboratory

**MontanaTech**  
THE UNIVERSITY OF MONTANA



**LG Chem**  
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CHANGING WHAT'S POSSIBLE