

Millivolt to Microvolt, How Your BMS Can Enable More Miles



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Range Challenges in BMS

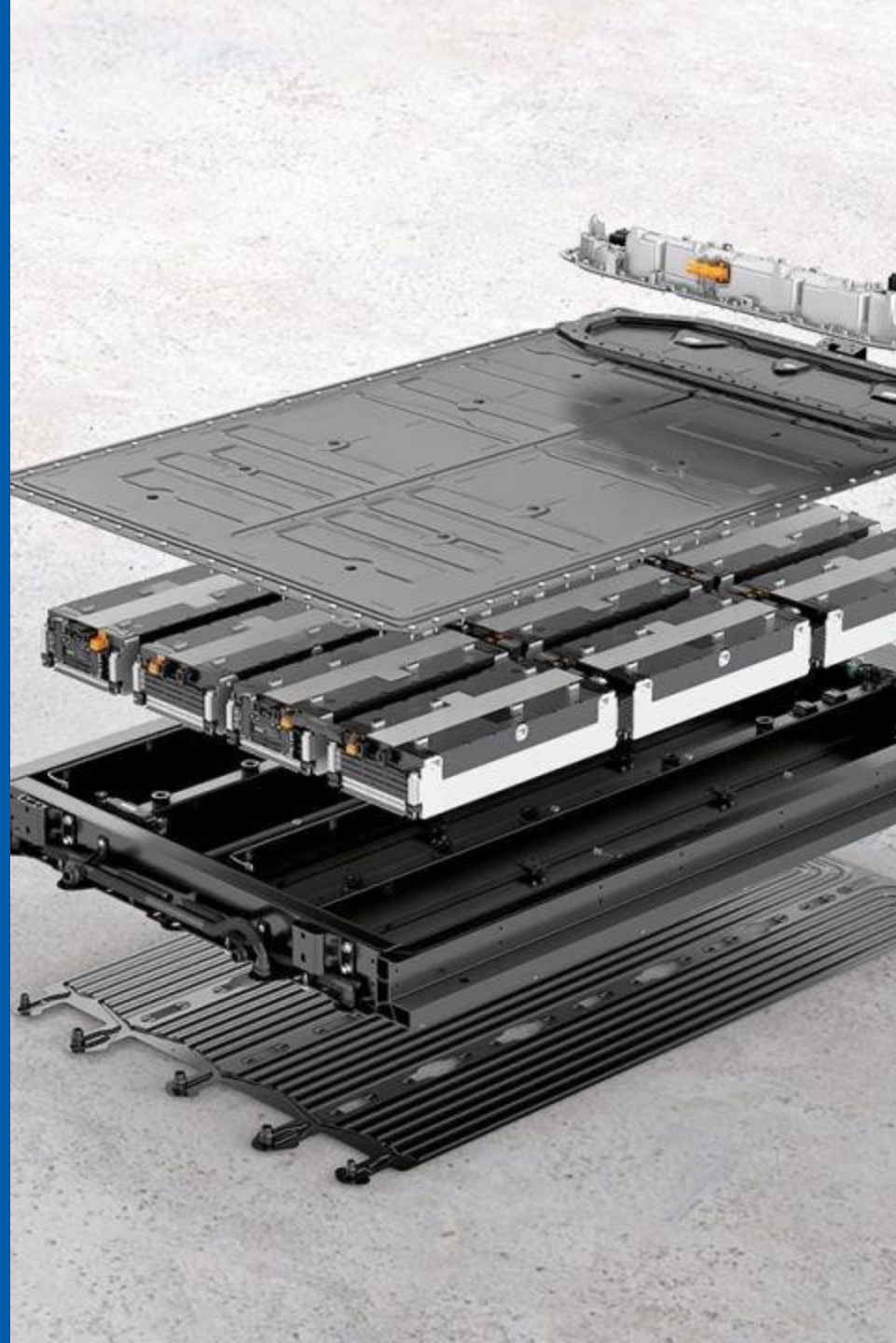
Range Challenges in BMS

- **Increase Pack Voltage / Capacity**

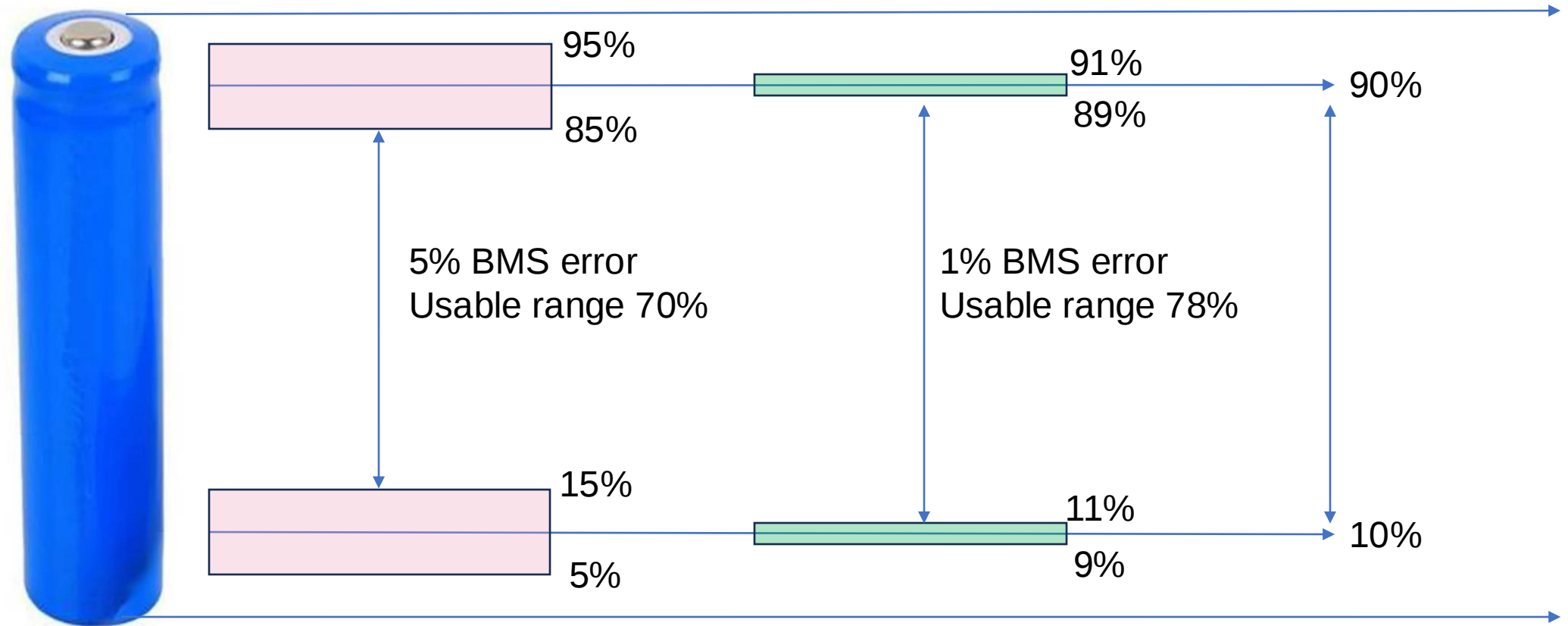
- Packs with 450V / 800V / 1200V in Market
- Wide adoption of 800V Pack
- DC fast charging 150 – 350kW
- Pack capacity settles in at 100kWh

- **Better Measurement**

- Focus on measurement error
- Better use of existing capacity
- Positive effect on usable pack lifetime

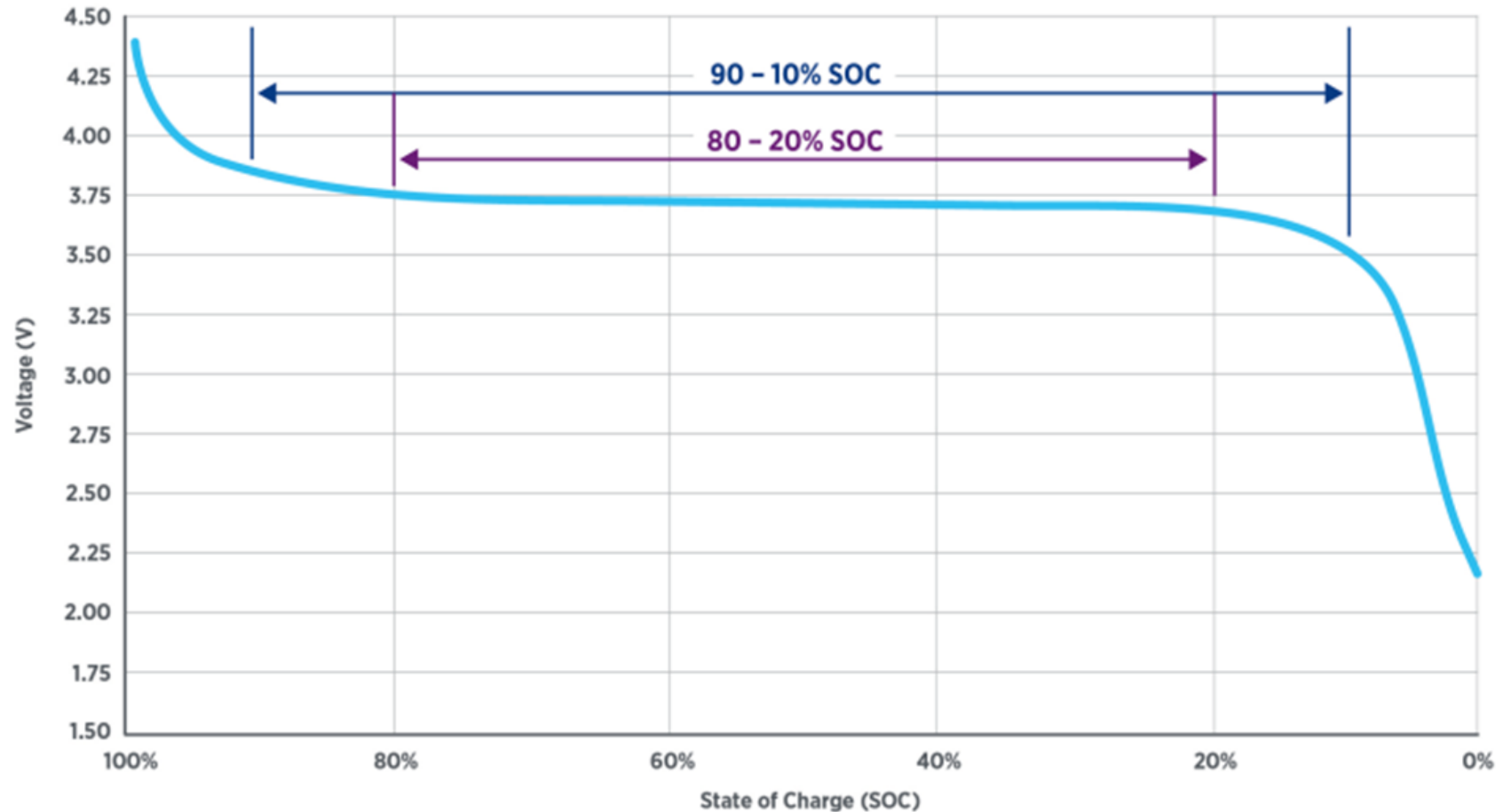


Improved BMS Accuracy Can Extend Range



What Level of Accuracy is Required?

Typical Li-ion Discharge Voltage Curve



Testing for BMS Accuracy

What factors prevent us from measuring in the microvolt range?

- **Voltage Drop**
 - Physics
(Resistance X Current = Voltage Drop)
 - Limit Cable length
 - OR Limit Path Current Capabilities



What factors prevent us from measuring in the microvolt range?

- **Thermal Offset**
 - Complex to assess
 - Temperature differences in environment, components and cables
 - Mating of material introduced by cables, connectors, PCB copper finishes and relay contacts in your signal path
 - Relay Contacts with 50uV Offset Voltage
 - Relay Contacts with 10uV Offset Voltage

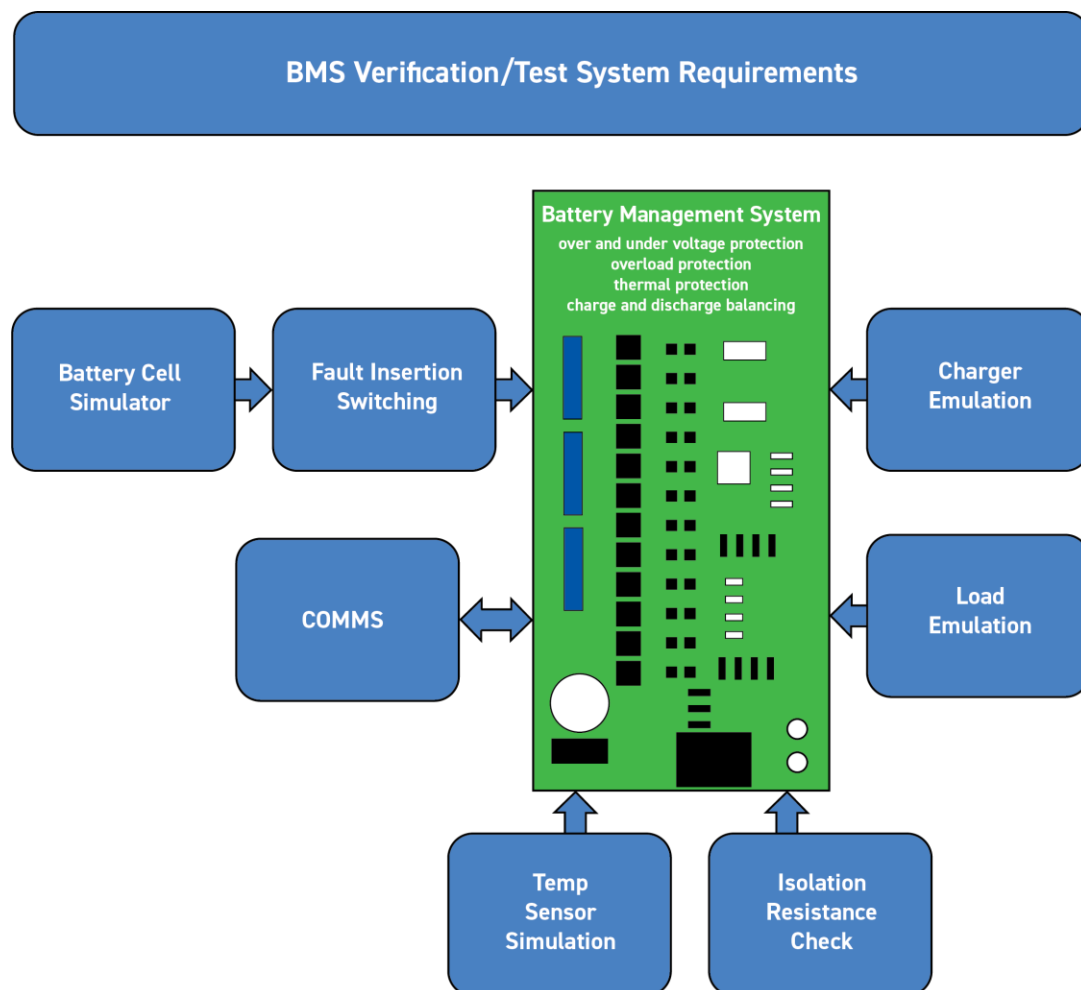


What factors prevent us from measuring in the microvolt range?

- **Wiring Quality**
 - Safety, signal integrity & noise
 - Underestimated
 - Stack voltage can go up to hundreds to over a thousand volts
 - Cable quality must match signal path & measurement accuracy to define signal integrity
 - Wiring protects signal path and measurement from environmental penetrator signals



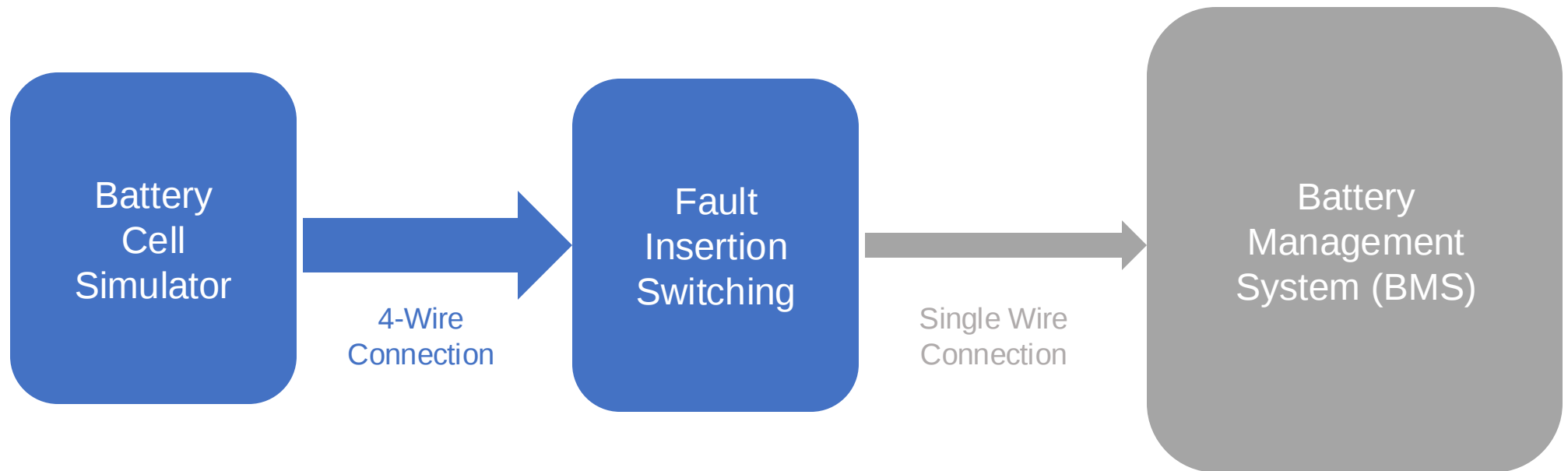
Outline of HIL System



Environment

- Cells
- Sensors
- Isolation
- Charging
- Communication
- Connectivity / Wiring

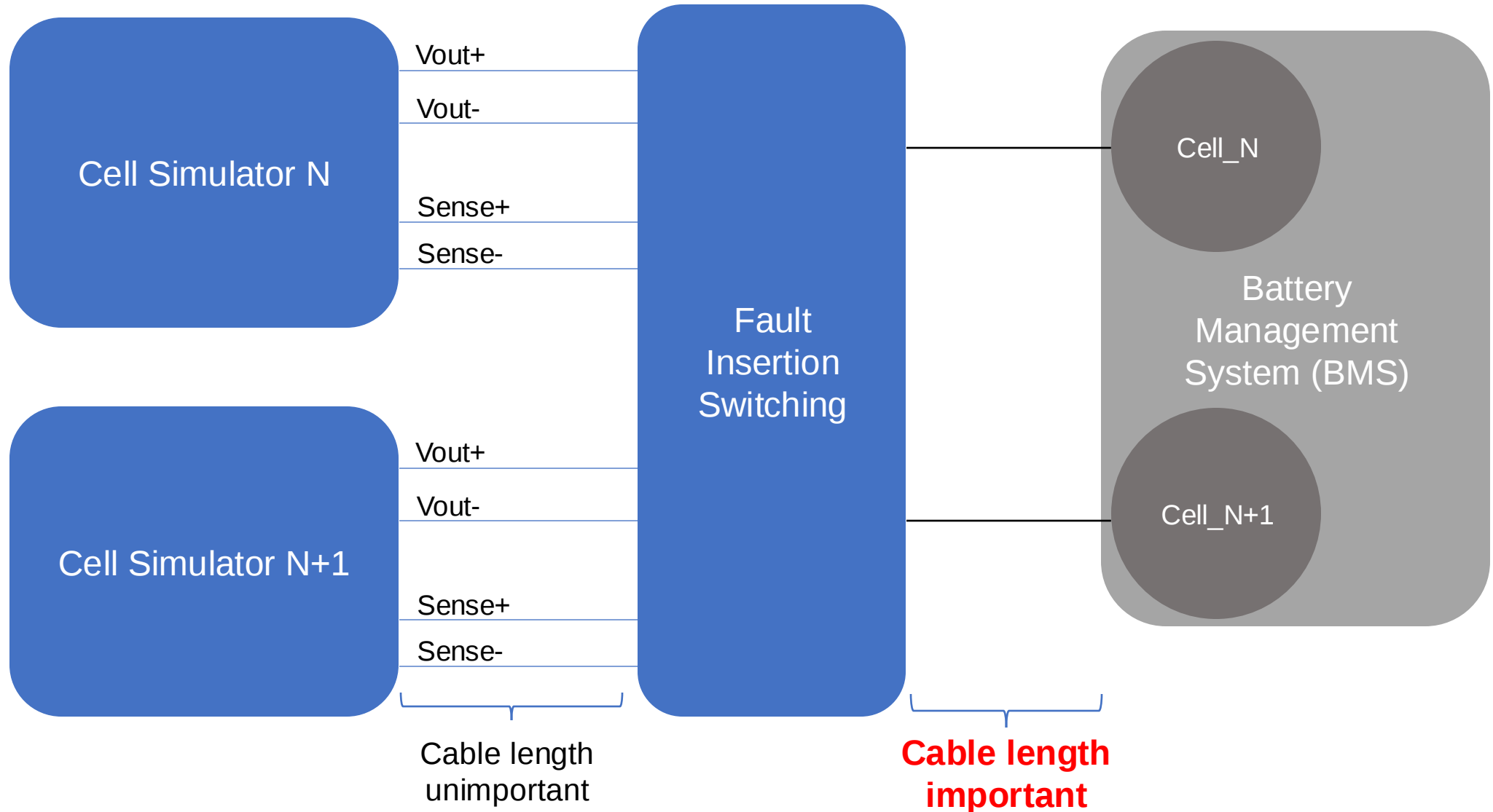
Battery Cell Simulator & Fault Insertion Switching



Blue = (COTS) commercial-off-the-shelf

Wiring Solutions

Battery Cell Simulator & Fault Insertion Switching





Wiring Solutions

Cable Length

- Reduce cable length (negate voltage drop and temperature differences)

COTS (known qualities) vs. DIY cables

- **Stability:** Issues that aren't noticed in millivolts could be an issue in microvolts
- **Termination Quality:** Increased losses
- **Density:** Every cell is connected to 4-wire
- **Mating of Connectors:** BMS vs. test system
 - Reconfigure challenges (more channels)
- **Selecting the Right Connectors**
 - Mating cycles (how often you open/close)
 - Voltage levels cables/connectors must sustain without affecting measurements
- **Compensation for Thermal Offset**

Scaling Plan

- Use more of the same types of cables
- Easier to reconfigure test system (add more faults, etc.)

Switching Solutions

Cell Simulator N+1

Vout-
Sense-

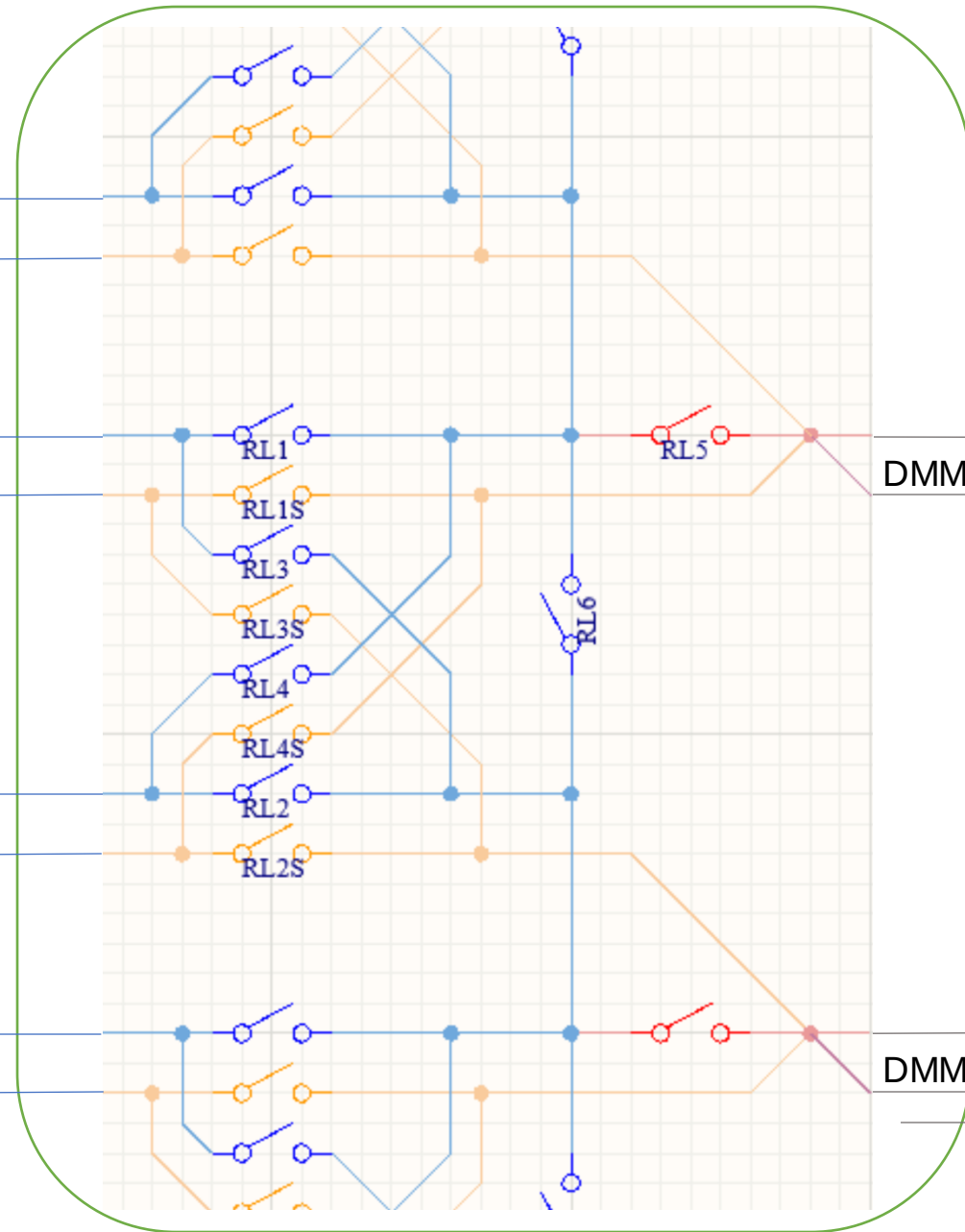
Cell Simulator N

Vout+
Sense+

Vout-
Sense-

Vout+
Sense+

Cell Simulator N-1



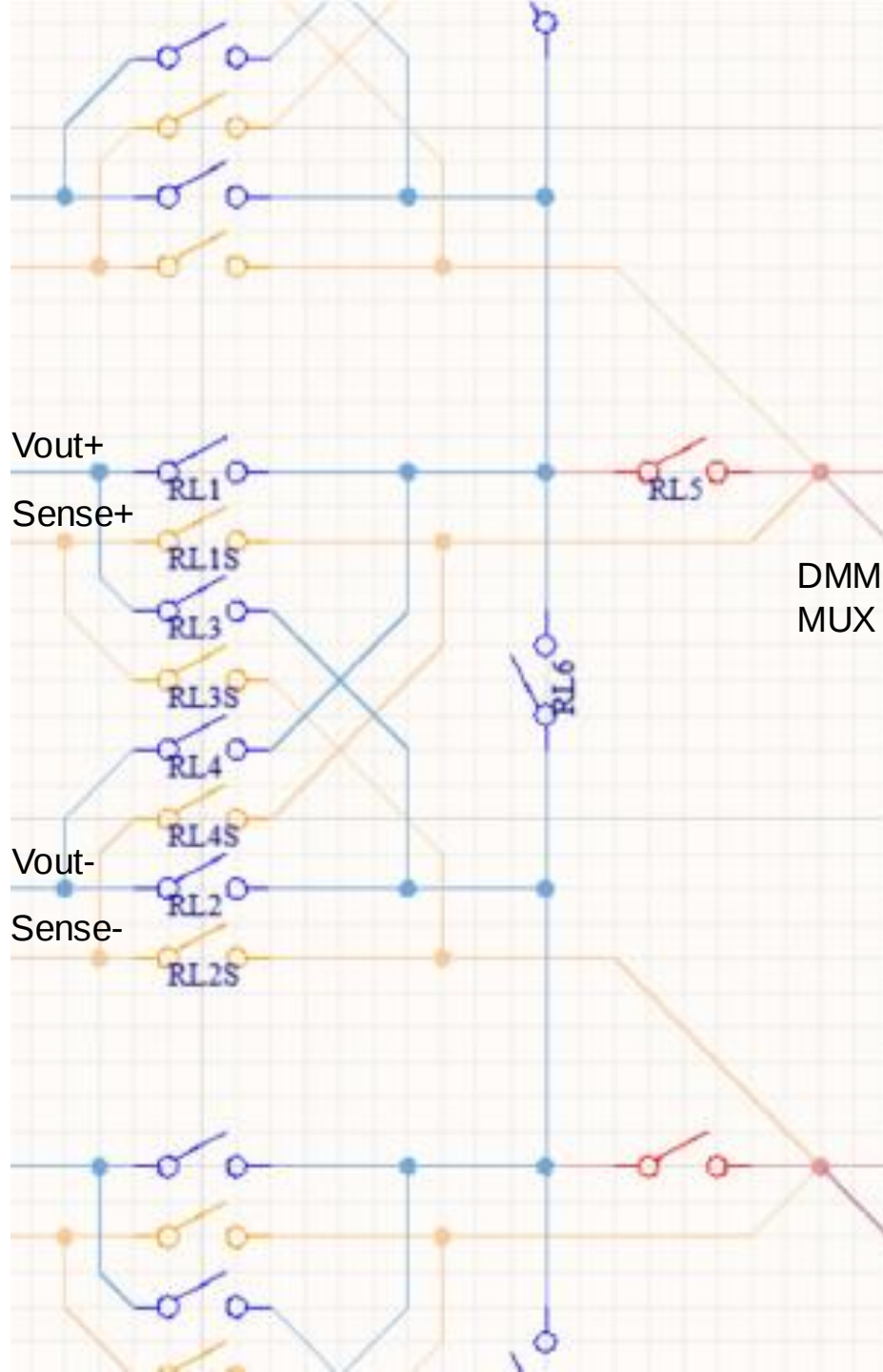
Cell_N

Battery
Management
System (BMS)

Cell_N-1

FIU

Switching Solutions



Access to Sense Lines with DMM (digital multi-meter)

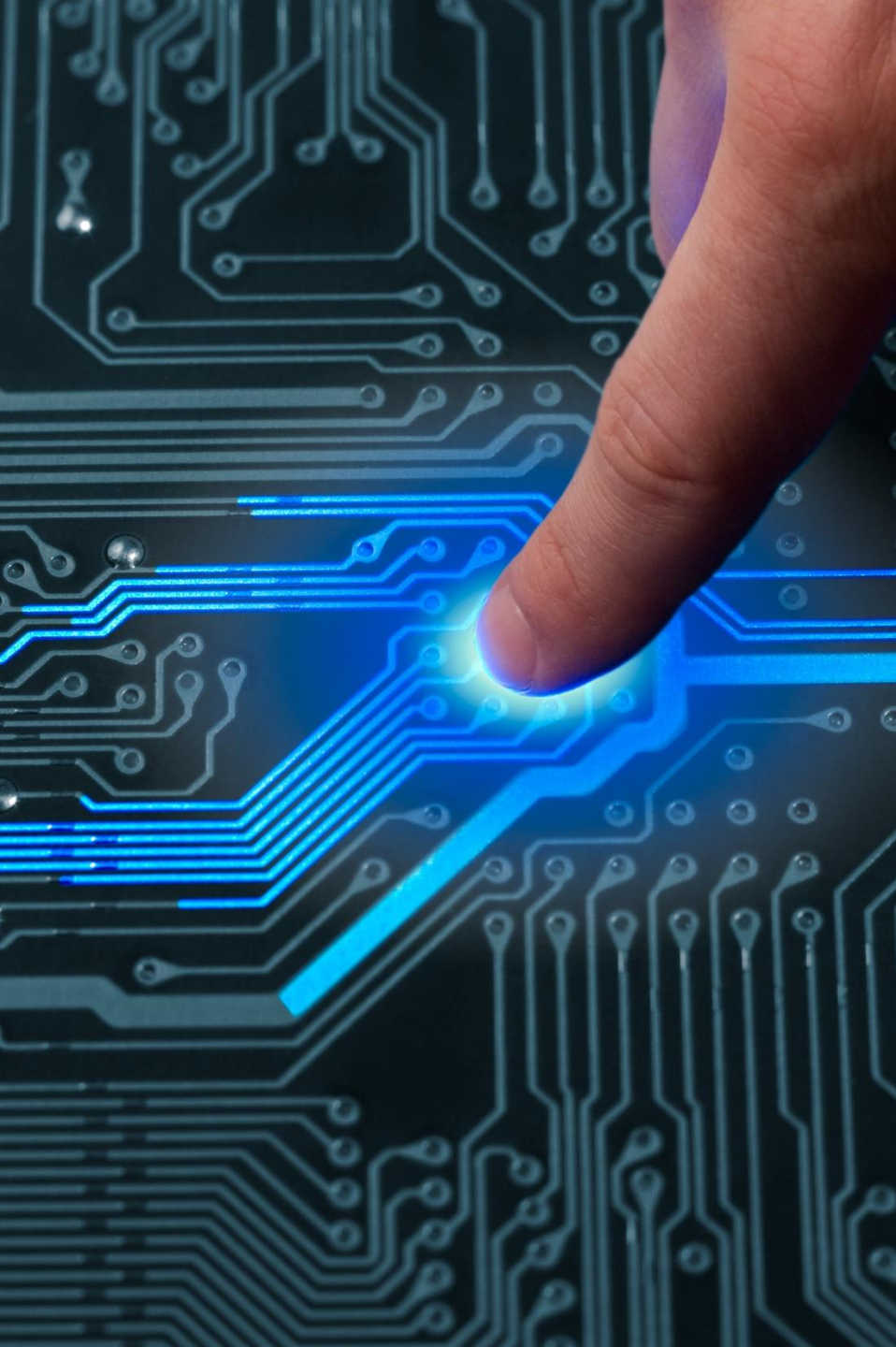
- Nanovolt measurement (higher accuracy)
- Multiplex to measure every cell

4-wire to 2-wire Measurement

- Depends on test needs for fault insertion
- Consider termination point

Relay Selection

- Manage sense lines: what sense lines are needed
- Consider relay suitability by function (i.e. sense vs. power & thermal offsets)
- Layout constraints: design rules to account for thermal offset for PCB



Switching Solutions

Mechanical Integration

- Cell emulators are bigger and wire lengths are too long
- Make wire lengths the same and as short as possible

Safety & Sustainability

- Certify system to correct rating
- Voltage/current protection: failsafes, interlocks, switching, sources
- Monitoring: chassis, temperature, entry points for interlocks, cleaning procedures, maintenance, system health
- Planned downtime, failure planning, etc.

Collaborative Approaches



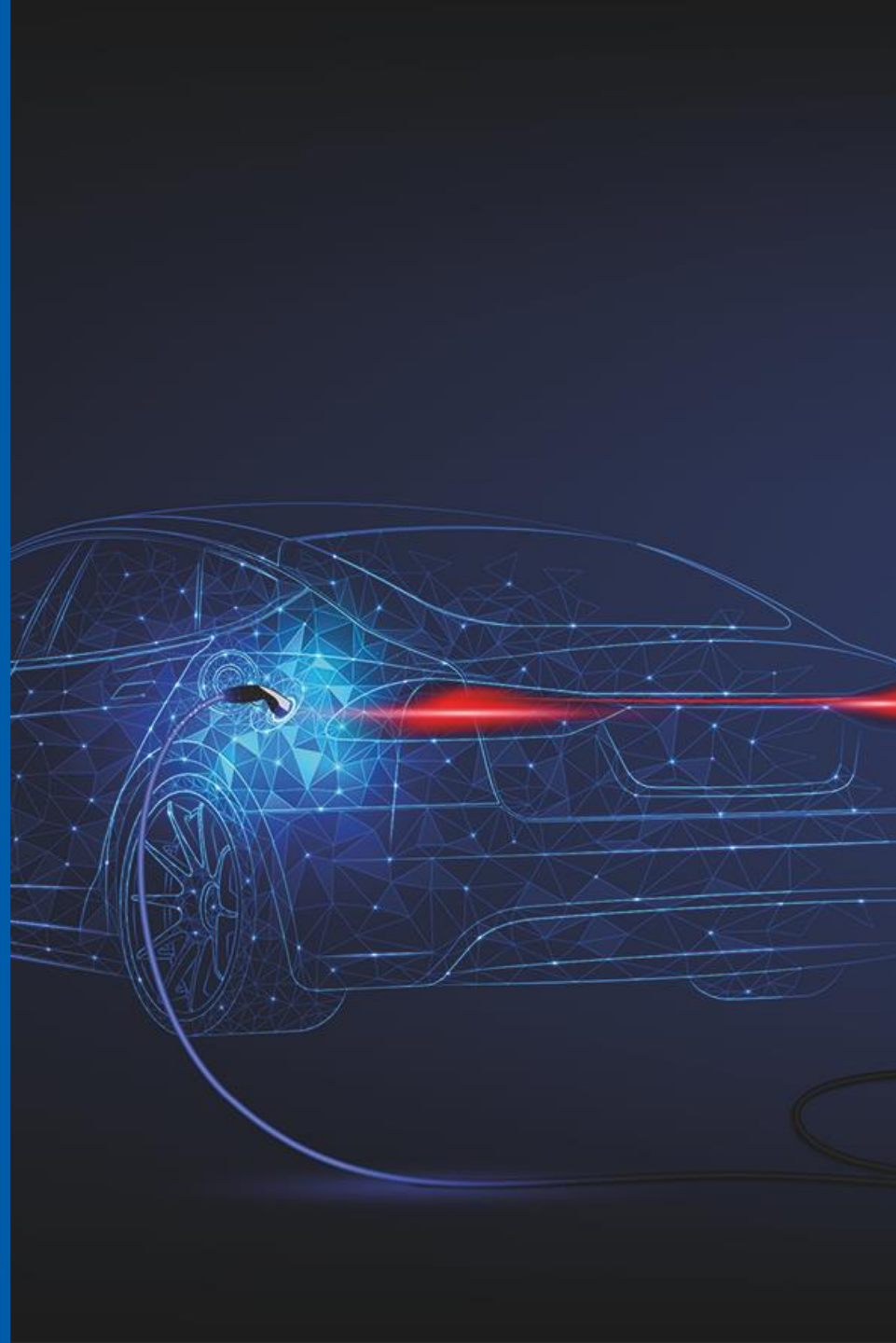
Collaborative Approaches

- **Wiring**
 - Standardize cables
 - Support 3rd party components
 - Guidance for DIY wiring
- **Switching**
 - Fault insertion use optimal switch
 - Path for microvolt accuracy measurement
- **Scaling:** combining components, wiring and switching for a flexible HIL system

Future of BMS

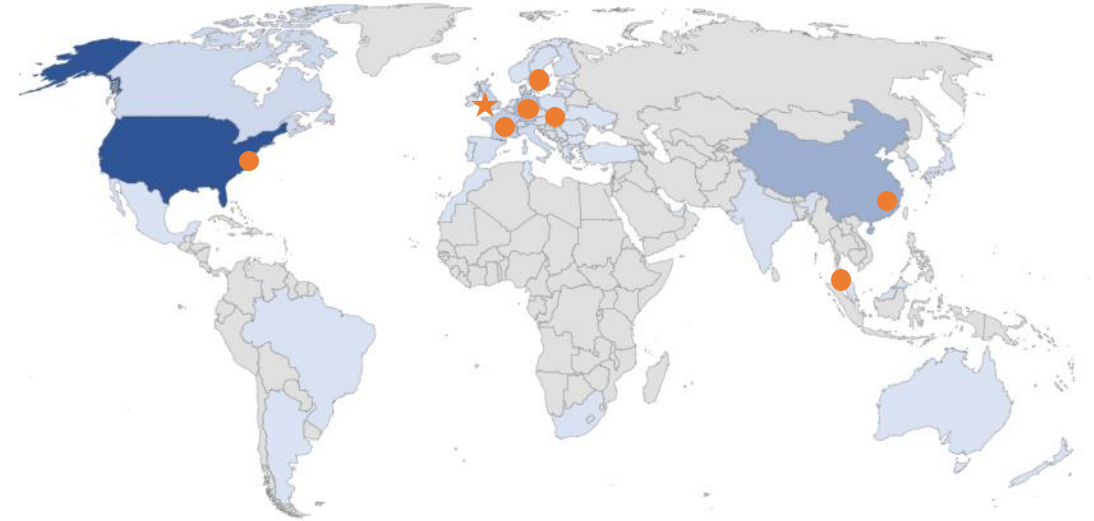
Future of BMS

- **Artificial Intelligence (AI):** more sophisticated ways to use measurement results
- **Smarter BMS**
 - Advanced cell impedance measurements
 - BMS dashboard
 - Higher car value in the secondary market



About Pickering Group

- Independent for 55+ years (3rd gen. family)
- Vertically integrated from relays to systems
- Worldwide sales into more than 50 countries
- 550 employees across eight sites
- Headquartered in England
- Manufacturing in England and Czechia



Pickering Electronics	Pickering Interfaces	Pickering Connect
Instrumentation Quality Reed Relays	Modular Switching and Sensor Simulation Modules	Standard and Custom Cabling Solutions
		

Q&A



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