

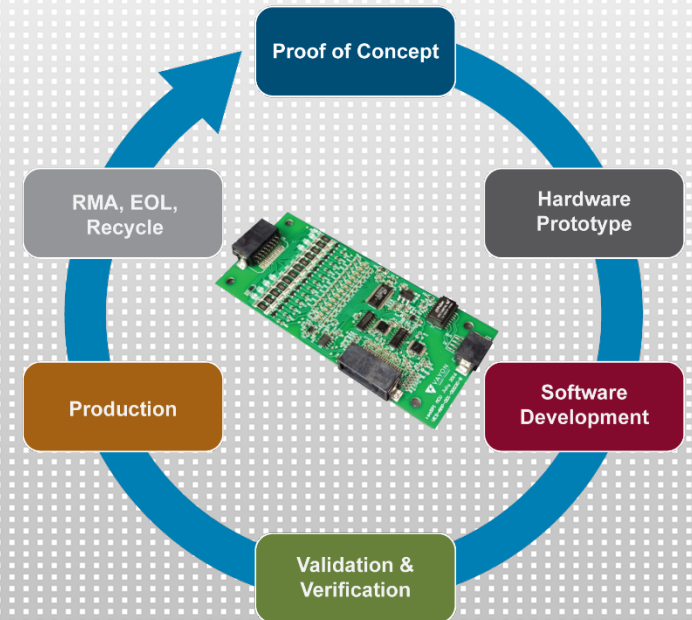


EFFICIENT BATTERY MANAGEMENT SYSTEM TESTING THROUGHOUT THE BMS LIFECYCLE

Peter Blume, President

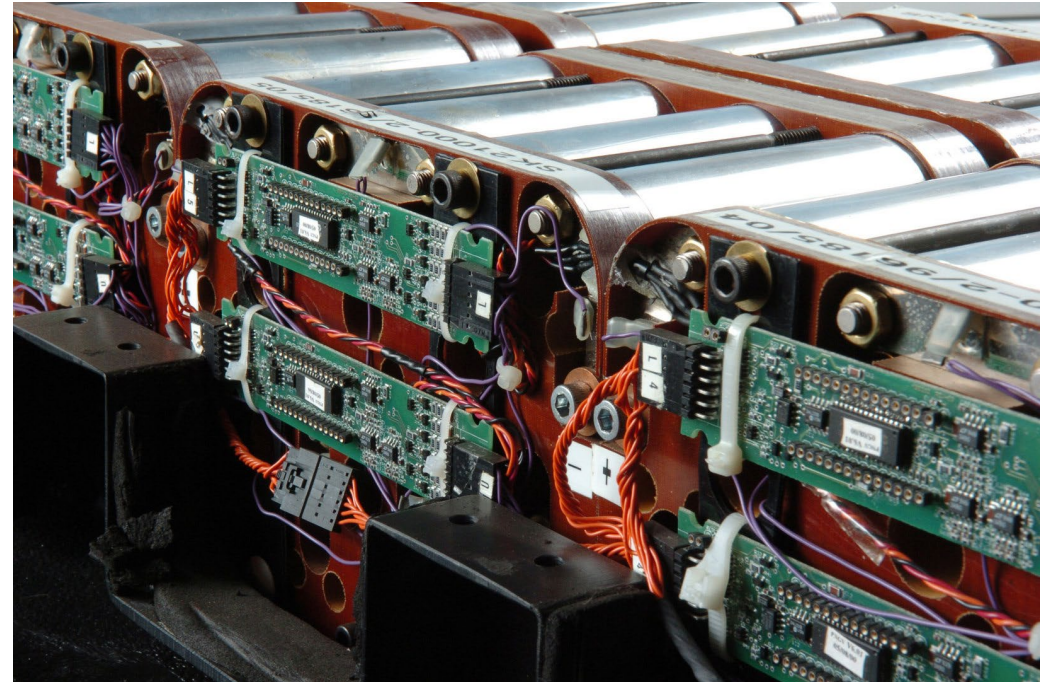
Grant Gothing, Chief Technology Officer

June 24, 2020



OVERVIEW

- Introduction
 - Extremely brief BMS tutorial
 - BMS lifecycle
- BMS Test Stimulus
 - Li-Ion cells
 - Traditional power supplies
 - Cell simulation hardware
- Types of BMS Testing
 - Engineering verification
 - Software validation
 - Design verification
 - Manufacturing functional test
- Q&A



BLOOMY QUICK FACTS

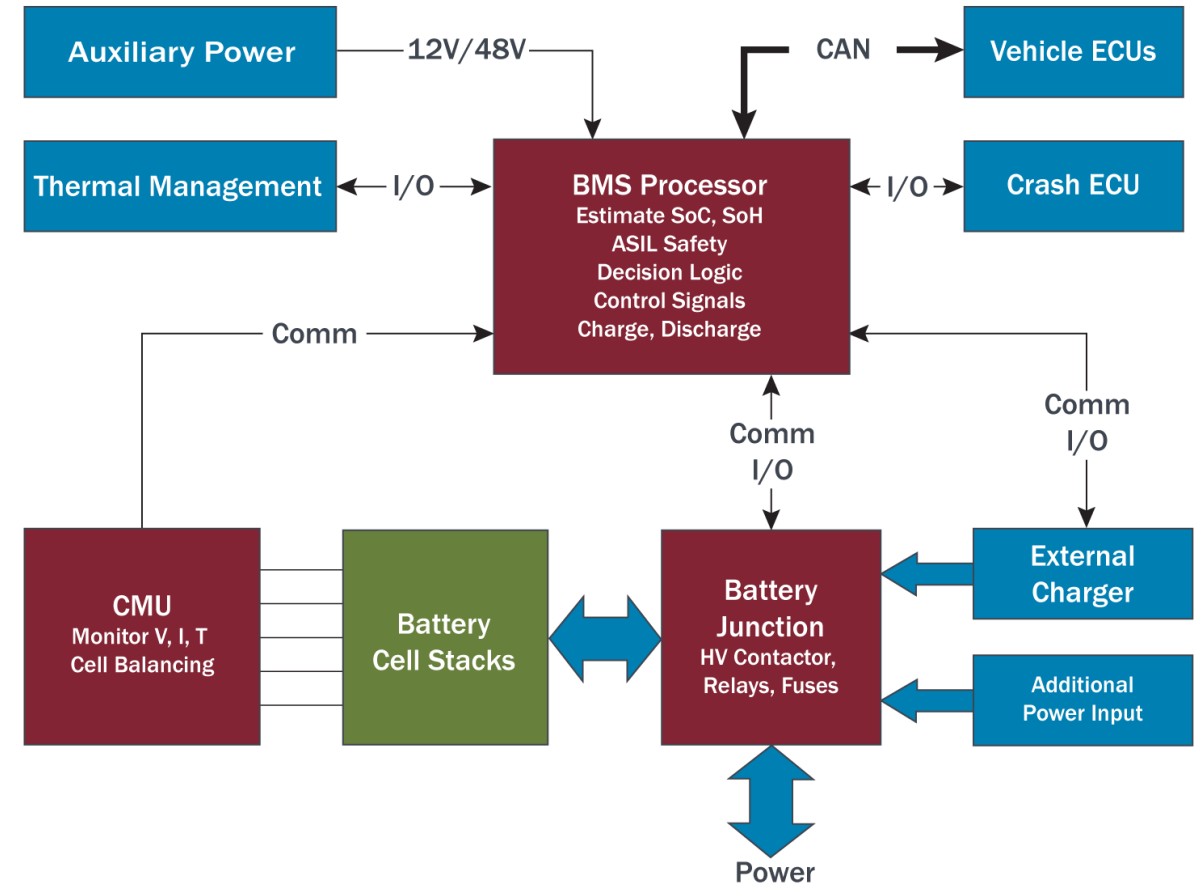
- Founded in 1992
- Automated testing equipment
 - Battery test & simulation (BTS)
 - Trans/Aero/Def Simulation systems (SIMS)
 - Universal manufacturing electronics functional test (EFT)
- NI Platinum Alliance Partner
 - Published “The LabVIEW Style Book” © 2007, Prentice Hall
 - “BMS HIL Test System Helps JLR Shorten Time-to-Market” Graphical Systems Design Award in 2016



WHAT IS THE BMS?

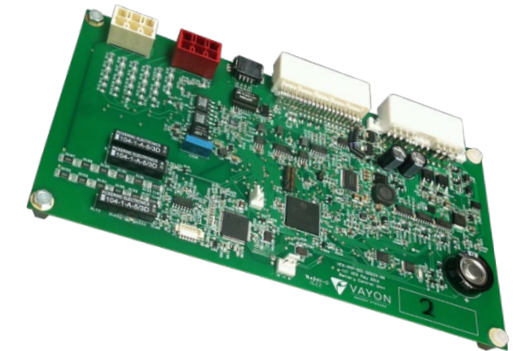
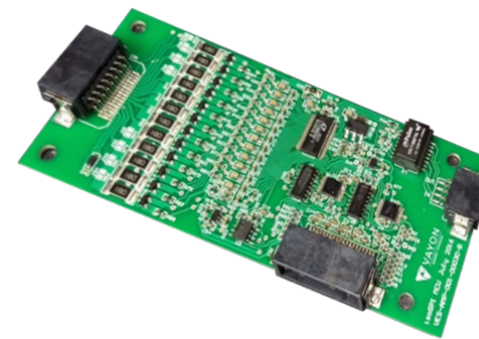
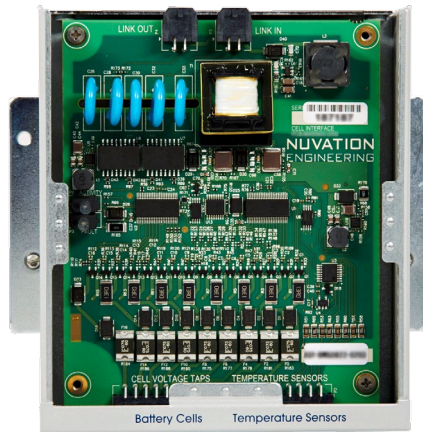
Battery Management System

- Monitor cell V, I and T
- Estimating the SoC and SoH
- Controlling the rate of charging and discharging
- Cell balancing
- Monitoring alarm levels and pack voltage
- ASIL functions
- Controlling the contactor(s)
- Communicating to the ECM and other ECUs



MANY BMS PCBA DESIGNS

- Module and pack configuration
- Topology
- PCBA Revision level



THE BMS IS CRITICAL

- Performance
- Longevity
- Safety
 - Hyundai Kona EV fires

“Hyundai Motor Company has since released an update to the vehicle’s Battery Monitoring System. While increasing the battery’s performance and longevity, the update also contains additional diagnostic health monitoring of the high-voltage battery and cells to ensure continued quality performance of the vehicle.”

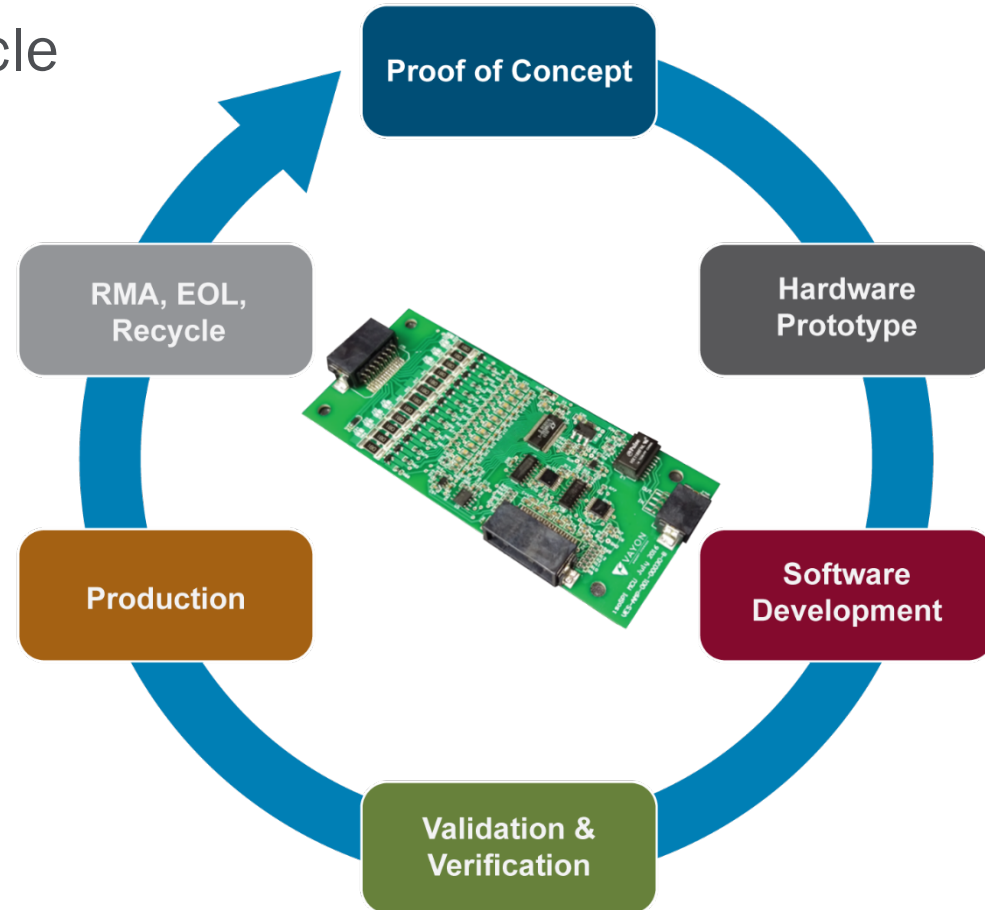
Reported by SBS News, InsideEVs, Road Show, others

- *Comprehensive testing is essential!*



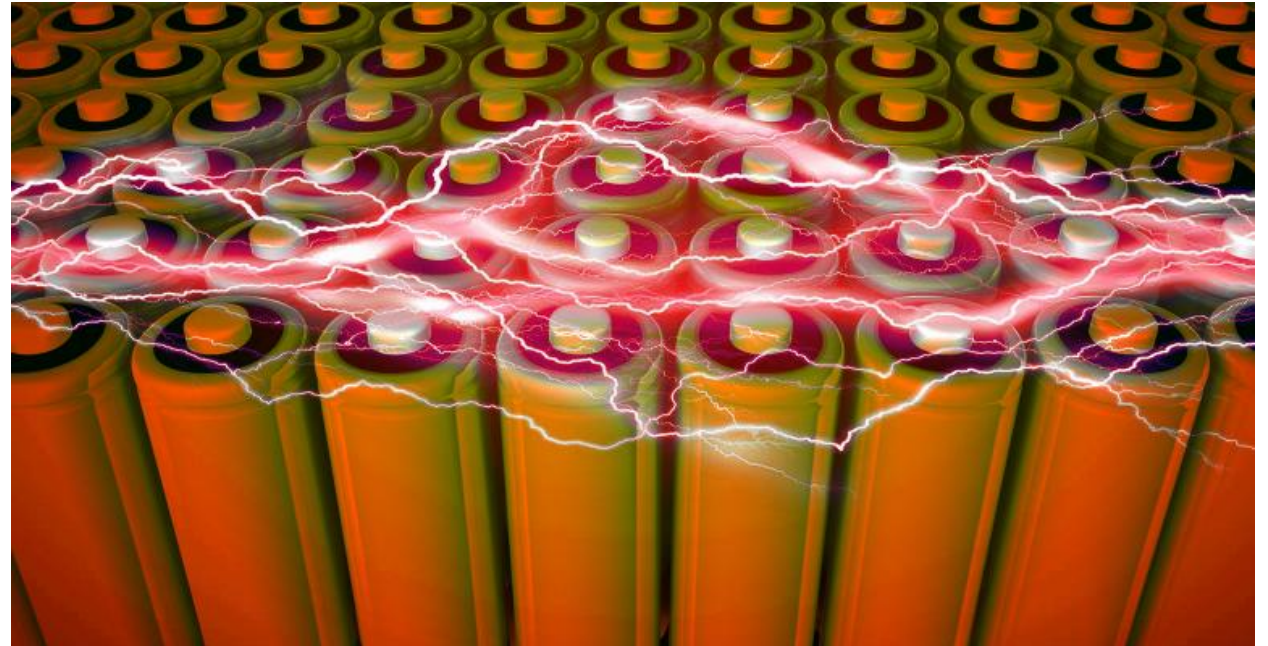
BMS LIFECYCLE

- Types of testing throughout the lifecycle
 - Engineering verification test
 - Software validation
 - Design verification
 - Manufacturing test



BMS TEST STIMULUS - ISSUES WITH LIVE LI-ION CELLS

- Safety
- Efficiency
- Throughput
- Repeatability
- Coverage
- Extremes
- Facilities



BMS TEST STIMULUS - ISSUES WITH POWER SUPPLIES

- Electrical characteristics dissimilar to cells
 - Noisy switching circuitry
 - High peak-peak ripple
 - Not sinking/sourcing
- Requires many instruments, filtering, and switching
 - Large, cumbersome and complicated
 - Very distracting for test engineers to design and maintain
 - Risk of altering the BMS design to accommodate the testing equipment behavior



CELL SIMULATON HARDWARE

- 12 Independently-programmable cells
- Cell voltage and current readbacks
- Sink and source current
- 1000V isolation
- Connect 200 cells in series
- Ethernet (LAN) and high-speed CAN communications
- Soft front panel executable software
- LabVIEW driver, CAN dbc
- 1U, 19" Rack mount enclosure
- Commercial, off-the-shelf
- FCC and CE certified

Battery Simulator 1200



CELL SIMULATION HARDWARE

- 24 Channels of switching for 2 Battery Simulator 1200 instruments
- Simulate short- and open-circuits on any cell
- ISO 26262 functional safety testing

Battery FIU

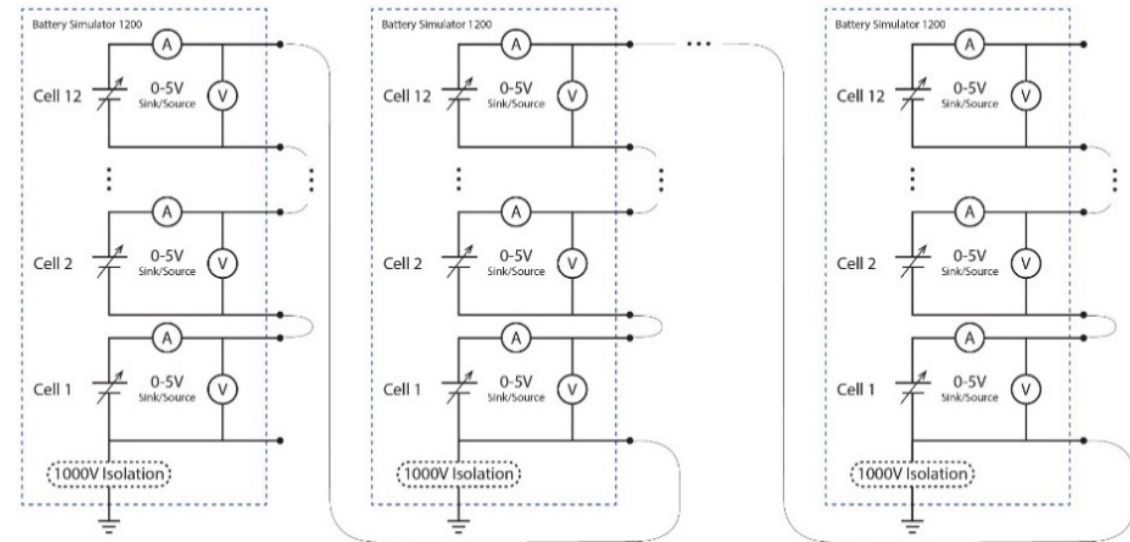


CELL SIMULATION HARDWARE

- 4-Terminal cell interface
 - Accurately controls the cell voltage at the BMS
- Modular
 - Simulate many different pack configurations from 12V to 1,000V
- Building block for all BMS testing equipment throughout the BMS lifecycle



Pin number	Signal
Pin 1	Sense+
Pin 2	Vout+
Pin 3	Vout-
Pin 4	Sense-

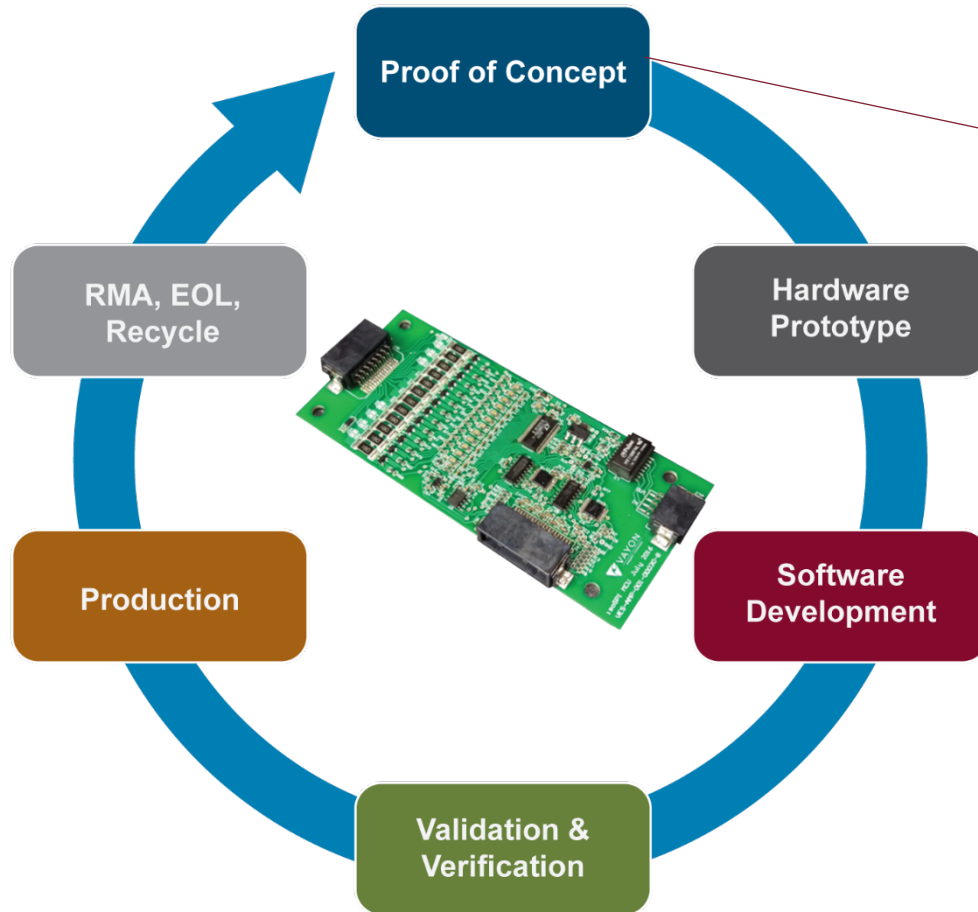


CELL SIMULATION HARDWARE

- Very high instrumentation density
 - 12 simulated cells
 - 12 cell voltage readbacks
 - 12 cell current readbacks
 - 1U, 19" rackmount enclosure
- Example configuration - >
 - 96 simulated cells, 192 readbacks
 - 19U, 19" equipment rack

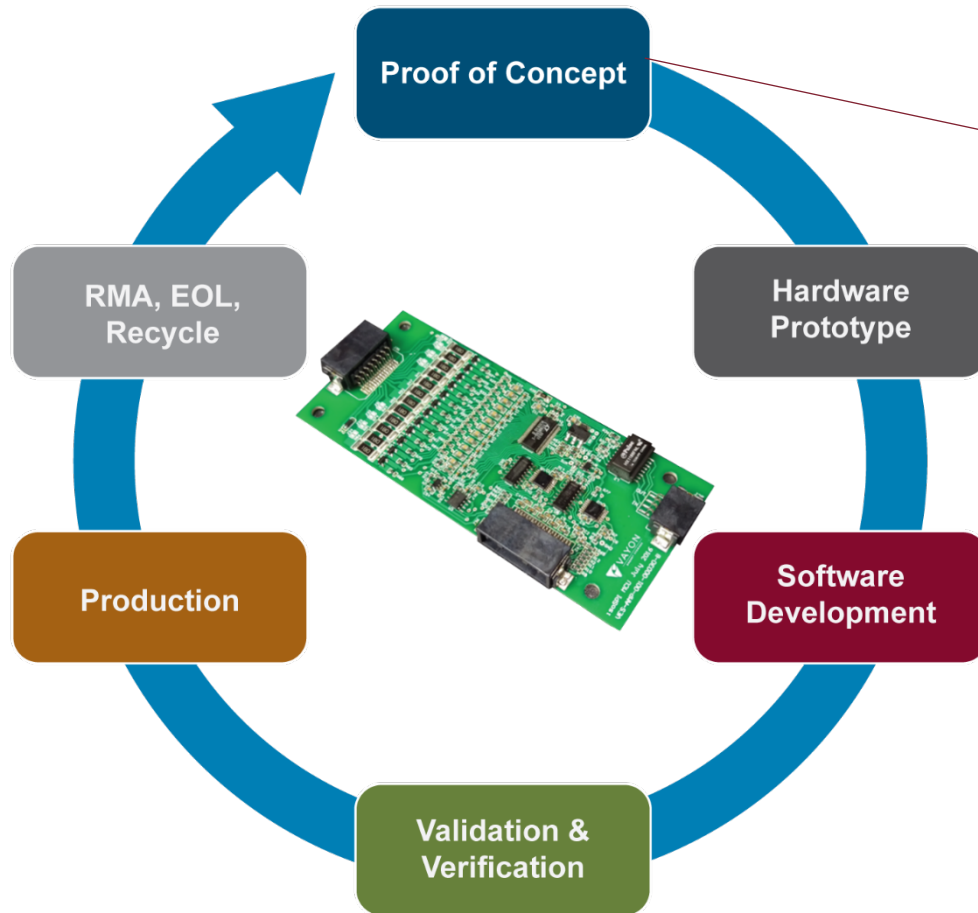


ENGINEERING VERIFICATION TEST



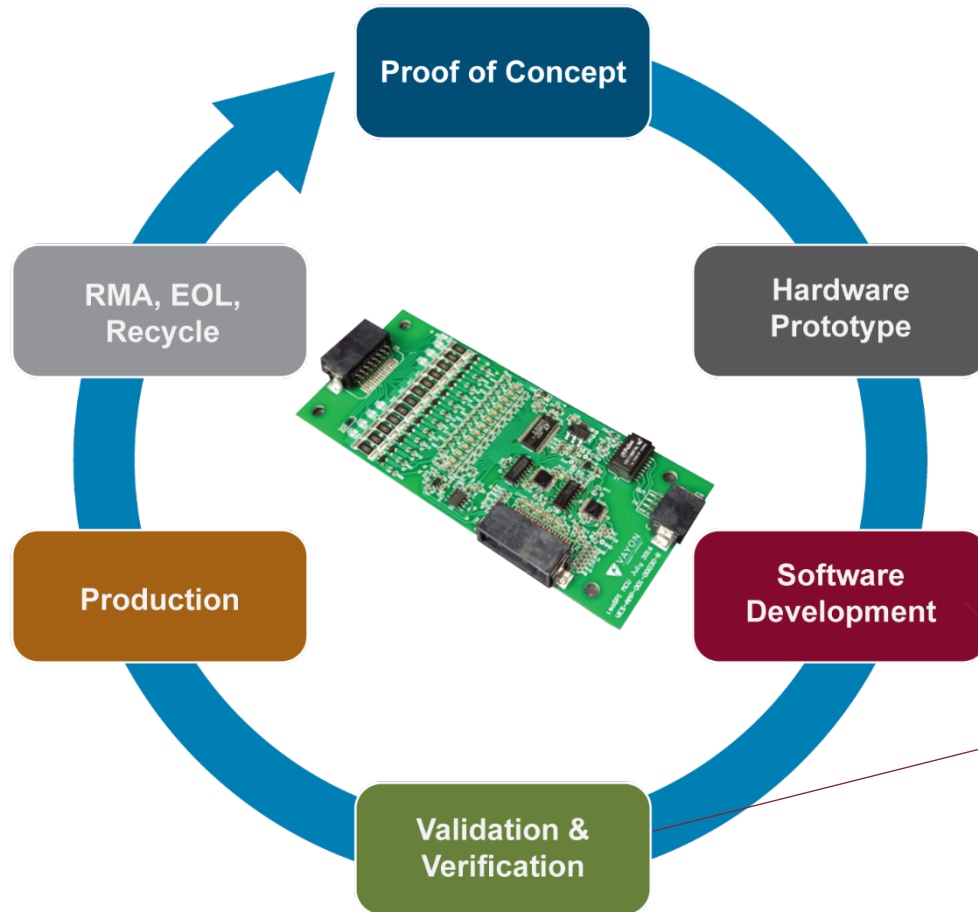
- Bench testing circuits using manually-operated instruments is common in early phases of BMS development

ENGINEERING VERIFICATION TEST

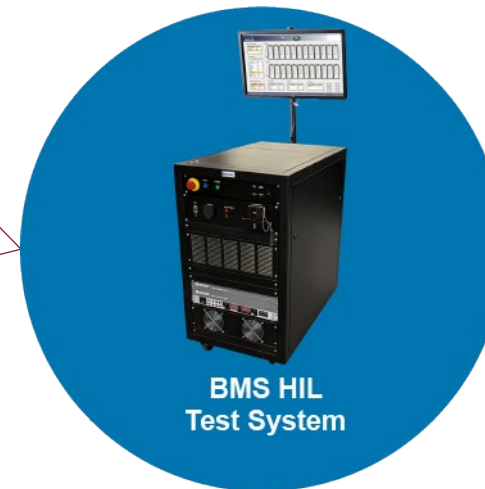


- Consider PC-controlled cell simulation hardware with soft front panel
 - More cells
 - Interactive control
 - Automated test scripts

BMS SOFTWARE VALIDATION

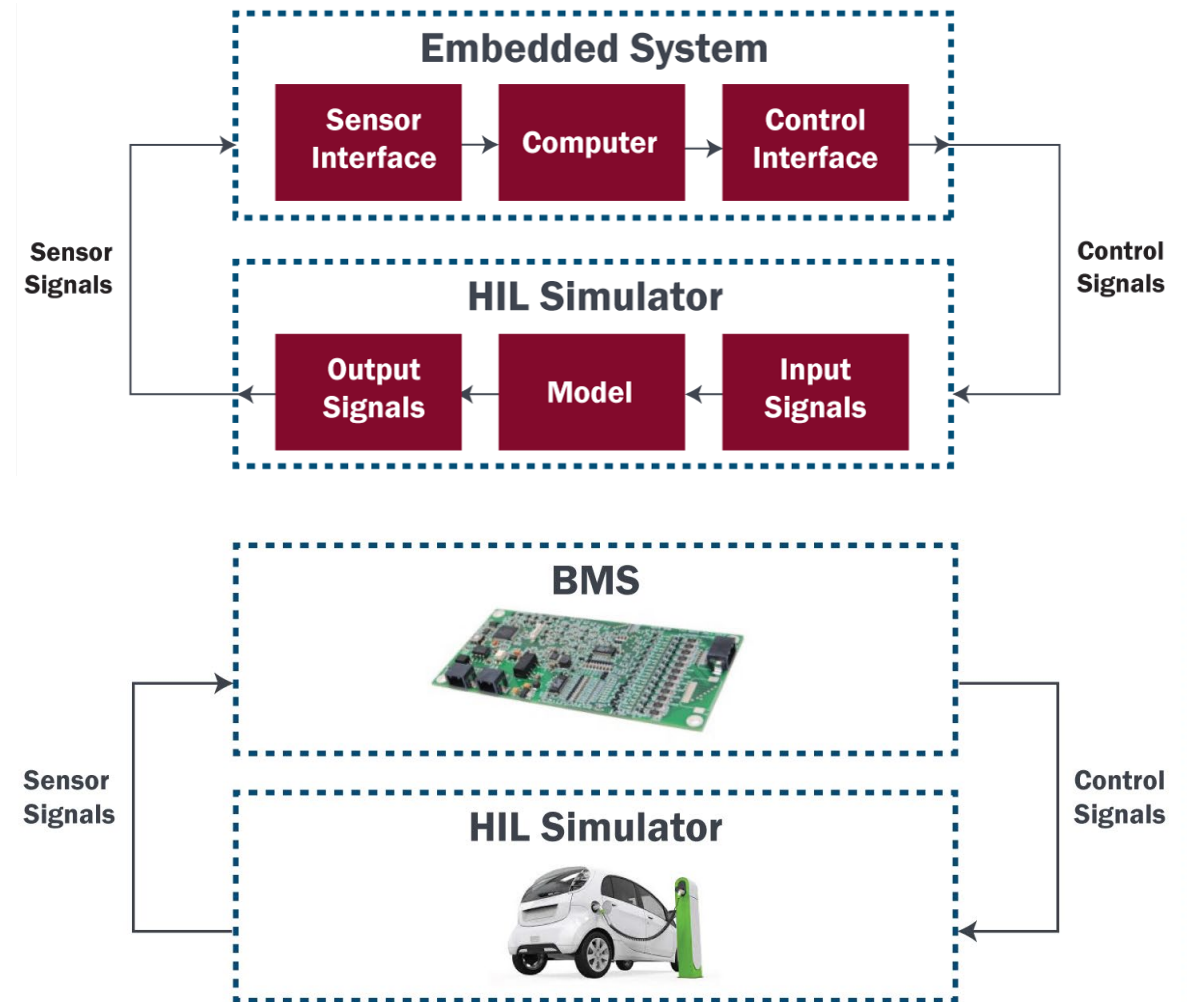


- Automated test system exercises and tests all of the BMS functionality
- Fault case scenarios
- Simulate drive cycles
- Regression testing



SOFTWARE VALIDATION WITH HIL TEST SYSTEM

- HIL = Hardware In the Loop
 - Closed-loop automated test system for testing embedded systems
 - HIL Simulator runs a mathematical model that simulates a plant or process
 - BMS HIL Simulator simulates battery and other EV subsystems
 - Cell model is derived through characterization of real cells



BMS HIL TEST SYSTEM

- Real-time hardware-in-the-loop battery simulator
 - Real-time computer and operating system
 - NI VeriStand real-time test cell software
 - Runs mathematical models in real-time
 - Supports the Mathworks Simulink, C++, LabVIEW and many others
- Simulates all of the signals that interface the BMS
 - Up to 200 series-connected cells
 - RTD or thermistor temperature simulation
 - Pack voltage and current
 - ECM, ECU Communications (CAN, LIN, SPI)
- Create and run test scripts
 - Drive cycles or load profiles
 - Fault case scenarios



BMS HIL TEST SYSTEM

- Validates BMS software and performs regression testing
- Investigates battery performance, ageing, imbalance, coulomb efficiency

“Major BMS firmware releases can now be rolled out within one week with good confidence of success, whereas similar projects in the past used to take well over a month, and with substantially less confidence.”

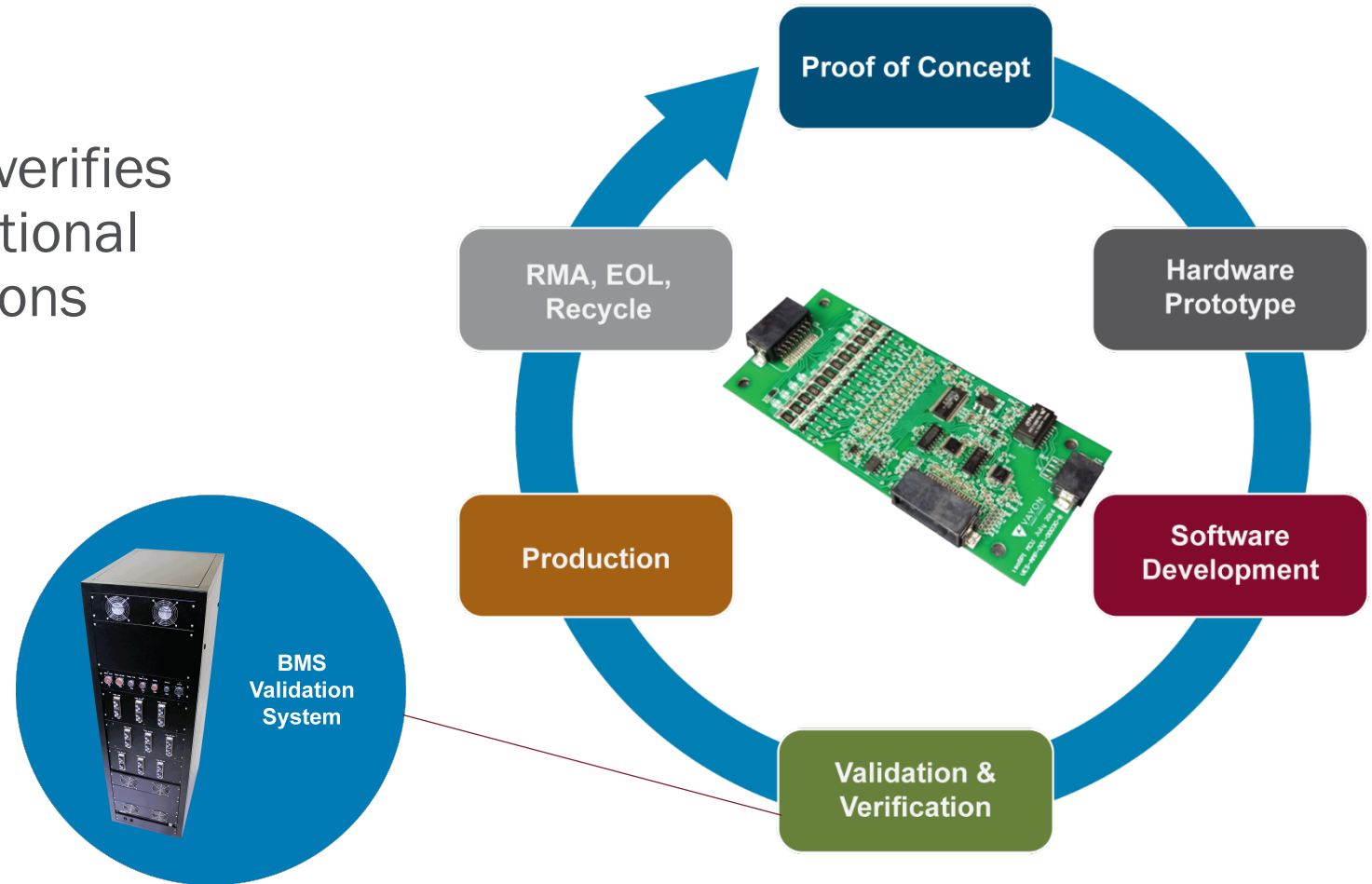
Miguel Angel Gama-Valdez, Principle Engineer, Jaguar Land Rover



- Attend “Demystifying BMS HIL Testing”
Friday, June 26th at 11:00AM ET (USA)

BMS DESIGN VERIFICATION TEST

- Automated test system verifies environmental and functional performance specifications
- HALT, HASS testing

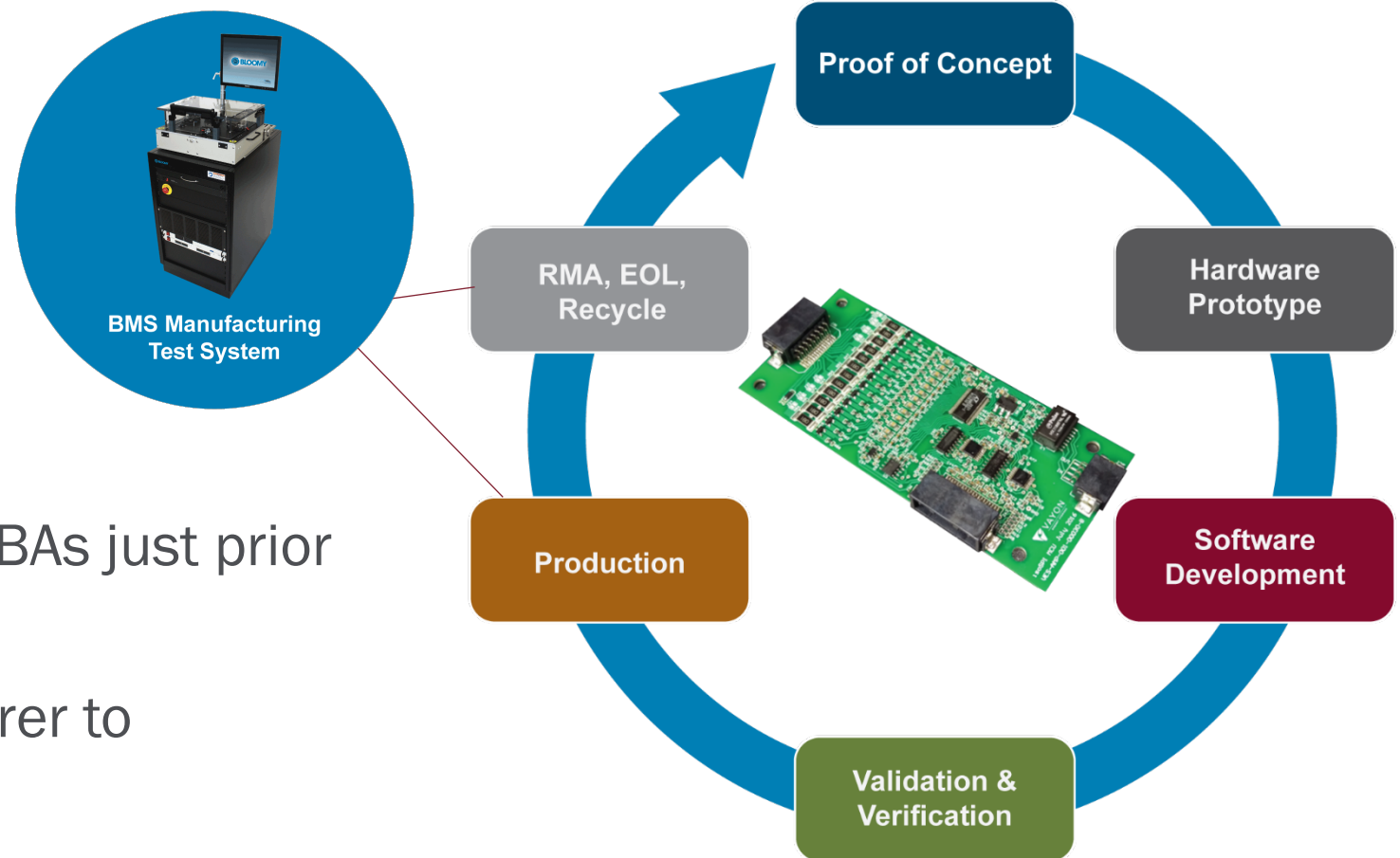


BMS DESIGN VERIFICATION TEST SYSTEM

- Verify all BMS specifications
 - Functional
 - Performance
 - Environmental: temperature, humidity, vibration
- Parallel testing of multiple BMS units
 - Instruments may be shared if managed carefully
- Automated test scripts with recipe of steps
 - Controls environmental chamber, pack conditions
 - May reuse for HALT, HASS testing



BMS MANUFACTURING FUNCTIONAL TEST



- 100% Testing of BMS PCBAs just prior to assembly in the pack
- Performed by manufacturer to eliminate defects

TRADITIONAL MANUFACTURING TEST APPROACHES

- In-Circuit BMS PCBA Test
 - Component-level testing
 - May not capture all defects
- Functional BMS PCBA Test
 - Eliminates defects
 - Improves yields
- Battery module test
 - Failed modules are expensive to fix
- Pack test
 - Defects are expensive and/or destructive



BMS MANUFACTURING FUNCTIONAL TEST SYSTEM

- Base rack with programmable instruments, cell simulation hardware
- Mass interconnect fixture receiver
- Interchangeable fixture heads
 - Bed of nails, edge connector
- Test executive software
- Operation
 - Loads BMS firmware and software
 - Calibrates cell monitors and current shunts
 - Runs automated test scripts
 - Generates test report



UNIVERSAL APPROACH

- Separate fixtures for BMS master, module and cell monitors
- One system tests many different BMS PCBAs
 - Fast product change-over
 - Small foot print
 - Reduces maintenance and cost



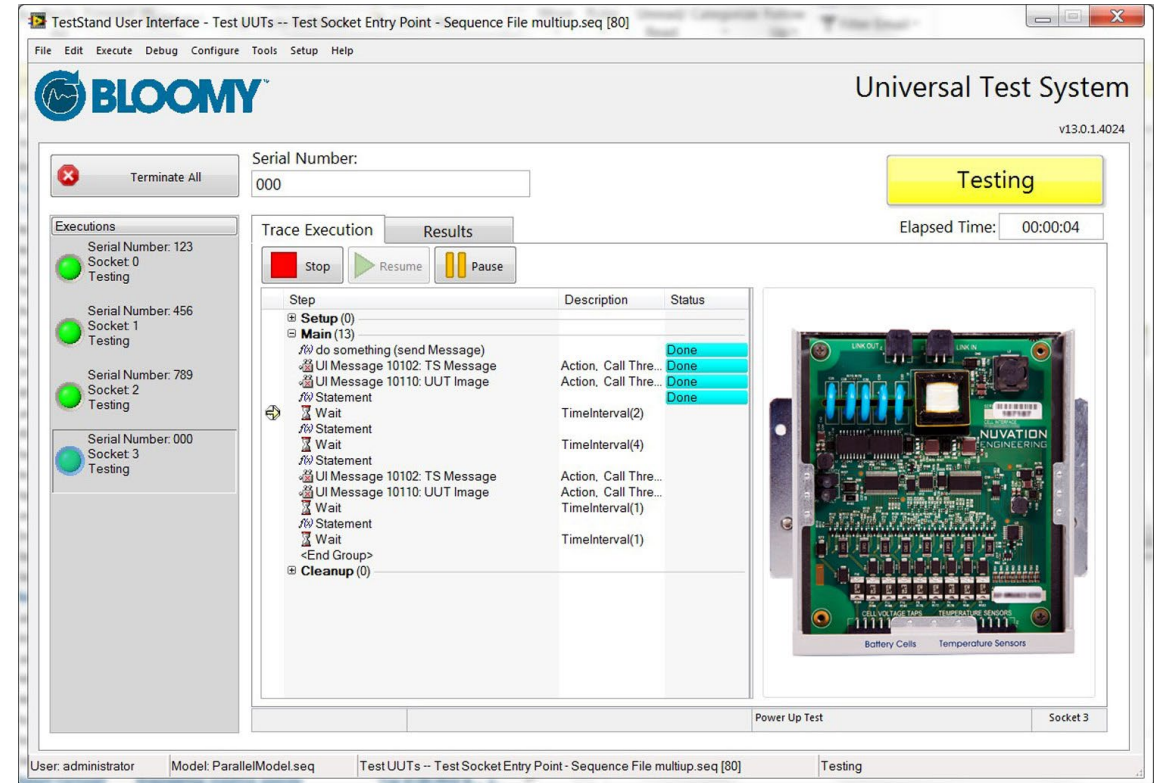
Many BMS PCBAs

Multiple Fixture Heads

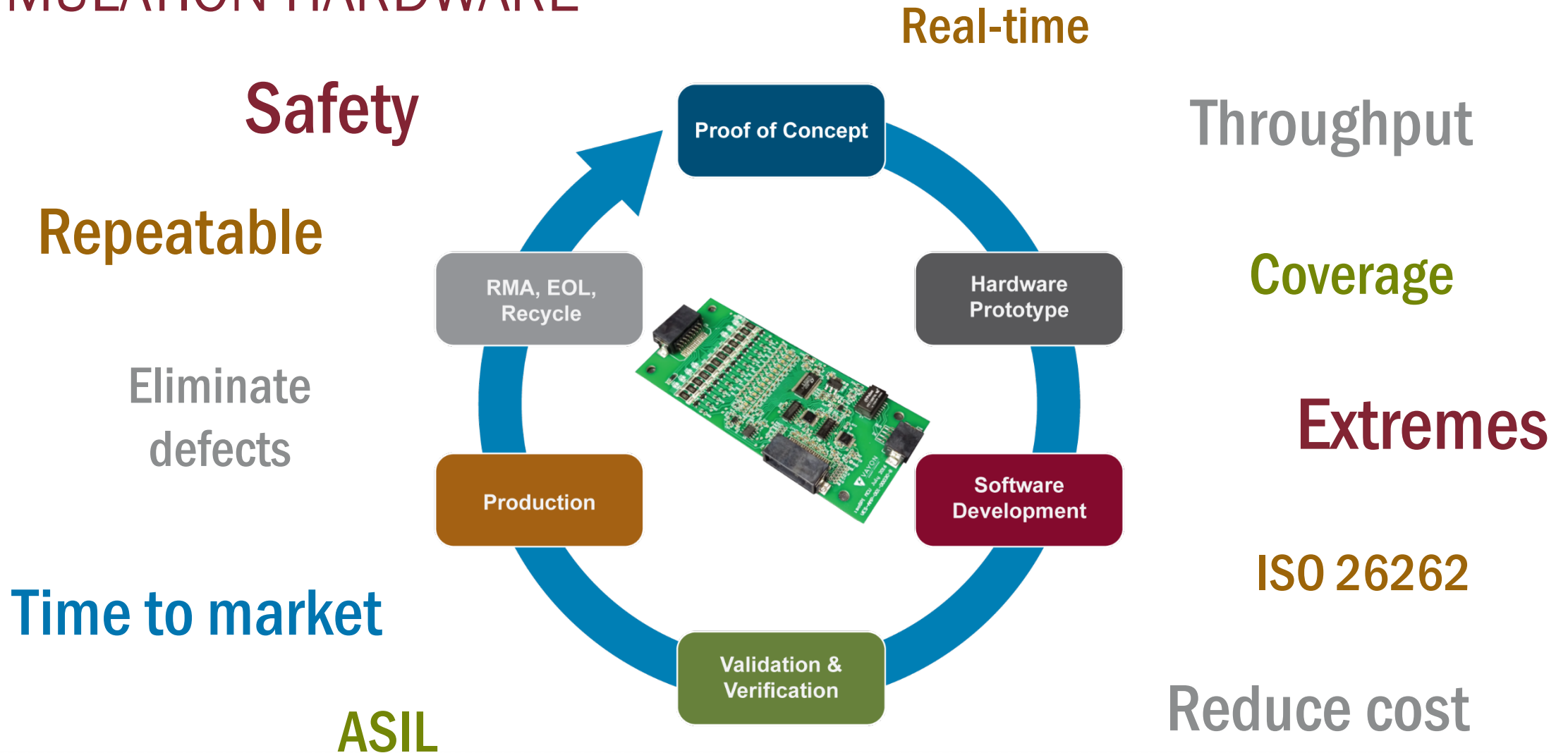
One Universal BMS Test System

TEST EXECUTIVE SOFTWARE

- Reduces development time, effort, cost, and maintenance
 - Hardware & measurement abstraction
 - Standard operator interface



BENEFITS OF AUTOMATED BMS TESTING WITH CELL SIMULATION HARDWARE



MORE INFORMATION

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“Demystifying BMS HIL Testing”

Friday, June 26th at 11:00AM ET (USA)

