Battery Validation Test
EV Powertrain Validation – NI Focus Areas

1. Battery Pack/Module Validation
   - Component durability/lifetime
   - Device functionality
   - Performance Characterization
   - Etc.

2. Traction Inverter - Signal Level
   - No high-voltage precautions required
   - Control System Development/Tuning

3. Traction Inverter - Power Level
   - Between Signal Level testing and Dyno
   - Hi-Fi Motor Emulation for controls development
   - Low-Fi Active Loads for durability/lifetime
The NI Approach

GETTING STARTED
Streamlined getting started experience minimizes schedule impacts and manpower requirements

I/O BREADTH
A broad range of I/O ensures you can meet the test requirements of advancing technology

CUSTOMIZABLE
A customizable, open platform lets you adapt to changing requirements and lowers investment risk

INTEGRATION
Integration with legacy and 3rd party systems helps you adapt to changing requirements and lowers investment risk

ADVANCED COMPUTING
State-of-the-art multicore, real-time computing and FPGA based products ensure you confidently test advancing technology
Architecture of an Automated Test System

Enterprise Data & System Management Software

Test Management Software

Test Module Programming Software

Instrument and Measurement Drivers

Computing  |  Timing and Synchronization  |  Test Integration  |  Instrumentation  |  Monitoring  |  Control

Fixture / Mass Interconnect
Architecture of a Platform-based Battery Test System

Partner Ecosystem

<table>
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<th>General-Purpose Products</th>
<th>Products Designed for Battery Validation Systems</th>
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<tr>
<td>CompactRio</td>
<td>Battery Test Software</td>
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<td>NI-DAQmx</td>
<td>Rack Infrastructure</td>
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<td>LabVIEW</td>
<td>Power Electronics</td>
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<tr>
<td>SystemLink</td>
<td>Automotive Network Interfaces</td>
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NI Service and Support
Where are we focused?

Validation workflows
- Durability testing
- Lifetime testing
- Performance characterization
- Other long-term testing

Installations with large, parallel deployments
Systems and Data Management
What makes battery validation challenging?

Battery Validation Test Characteristics

• Potential for very long test times
• Rapidly changing DUTs & Test Requirements
• Large, parallel deployments
• Industry push towards lights-out testing
What does this mean for designing a test system?

Battery Validation Test Needs

- **Stable**, sometimes month-long test executions
- Support for true, **multi-up** testing
- **Quickly adapt** to changing test requirements and DUT interfaces
- Tools for **system management** and **software deployment**
- Tools for **data management**, **analysis**, and **reporting**
## Design Implications

<table>
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<tr>
<th>Design Implications</th>
<th>Details</th>
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<tr>
<td><strong>Stable, sometimes month-long test executions</strong></td>
<td>Real-time operating system &amp; Infrastructure options for system stability (UPS)</td>
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<tr>
<td><strong>Support for true, multi-up testing</strong></td>
<td>Ability to independently start/stop executions running concurrently</td>
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<tr>
<td><strong>Quickly adapt to changing requirements and DUT interface</strong></td>
<td>Hardware Abstraction Layer w/ support for 3rd party tools</td>
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<tr>
<td><strong>Platform-based system designed for flexibility and expansion</strong></td>
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<td><strong>Tools for system management and software deployment</strong></td>
<td>Tight Integration with SystemLink and Enterprise Tools</td>
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<td><strong>Tools for data management, analysis, and reporting</strong></td>
<td>Tight Integration with Data Management Software Suite &amp; Enterprise Tools</td>
</tr>
</tbody>
</table>
Potential Solution Paths:

**No RT Execution Currently**
- Limited sequencing support
- Limited multi-up support
- Limited SystemLink Integration

**VeriStand + NI TestStand**
- Limited multi-up support
- Complex custom device development
- Limited SystemLink Integration without TestStand

**Other?**
- Custom LabVIEW?
- LabVIEW + TestStand?
- DCAF?
Current Solution: DCAF
Distributed Control Application Framework

• Execution on Windows or Linux RT

• Support for multiple, independent execution engines on a single target

• Extendable, plugin-based architecture:
  - Flexible hardware abstraction layer
  - Integration points for enterprise tools

• Tight, customizable integration with SystemLink tools.
Software architecture block diagram

1. Main Engine
2. Data Management Engine
3. Safety Watchdog
4. Measurement I/O plugins
5. Data Publishing Plugins
6. User Interface Plugin
7. Test Sequencer plugin
8. Datalogger plugin
Measurement System Specifications

- Real-Time OS based measurement and control system
  - 4 CAN interfaces (HS/FD, LS/FT)
  - 24 Cell Voltage Measurement Channels
  - 24 Cell Temperature Measurement Channels
  - 8 DI/8 DO Digital Communication Channels w/ PWM support
  - 1 RS-232, 1 RS-485 Communication Channel

- External Power Supply for low-voltage supply
  - 1 Channel, 0-100V, 216W

- Due to NI’s platform based approach, I/O can be added or removed to customize tester to specific customer needs
NI Battery Cycler Overview

- Scalable to 1200V/1600A
- Fiber-optic interface for high speed, low interference control
- Bi-directional support with power regeneration back to grid
- Includes high-accuracy measurements for Voltage and Current supply
HOW DO YOU TEST AN ELECTRIC VEHICLE POWERTRAIN?

CHRIS GARRATT
BUSINESS DEVELOPMENT MANAGER
c.garratt@austinconsultants.co.uk
Established 2005, Alliance Partner for over 10 years.
Highly skilled team of system architects and engineers: 8 CLA’s, 2 CTA’s, 2 CLEDS.
Offices in London, Bristol & Sheffield.
Specialisms: FPGA, HIL (VeriStand), Embedded, TestStand, DIAdem.
Python, Data Science, Condition Monitoring.
WHITE BOX FOR COMPLETE TEST CELLS

- Customers can have complete flexibility over what goes into the cell.
- The Data Acquisition and Control component is a small portion of the overall cell.
- A cell can cost between €700k and €5M depending on functionality.
- There are companies that can do the integration for you and provide a complete ‘White Box’ test cell.
PROVENTIA TEST SOLUTIONS OPEN APPROACH

- Modular test cells constructed from containers.
- Customer can choose from a selection of dyno and test vendors.
- Proventia take responsibility for integration of all systems and project delivery.
- Can be expanded in phases.
- Much faster project delivery times compared with traditional approach.
EV POWERTRAIN ARCHITECTURES

Native EV will make all drive configurations possible on one platform.

Different performance models could be entirely based on battery pack.

Greater flexibility of component placement due to smaller component size, and decreased positioning constraints.

Some designers moving towards integrated designs, which reduce weight and simplify thermal management (but not all).

(REF: MCKINSEY&COMPANY)
EV POWERTRAIN TEST CONSIDERATIONS

- Multi-Domain Engineering
- Evolving Control Logic
- New Battery Chemistries

- Power Distribution Module
- Inverter
- Traction Motor
- DC/DC Converter
- Auxiliary Battery
- High-Voltage Battery

- Passenger Heater
- AC Compressor
- Battery Heater

- Charge Port
- Onboard Charger
- External Charger

- Integration with Grid Standards
- High Power Electronics

COMPONENTS:
- Energy Storage
- Propulsion
- (Power) Electronic and Charging
- Thermal Management

CABLING:
- DC Fast Charge
- High-Voltage DC
- Low-Voltage DC
- AC Voltage

Image courtesy of National Instruments
EV DYNAMOMETER

320 kW dynamometer

570 kW dynamometer

Dyno Drive Inverter

Forced cooling (fan)

Torque meter

E-motor (DUT)

E-motor inverter

Battery pack

Battery Simulator

Facility DUT inverter

E.g. 900V, 450A

E.g. 500kW

EV DYNAMOMETER

320 kW dynamometer

570 kW dynamometer
TRADITIONAL VENDOR OFFERING

• Developed from ICE proposition
• Bespoke
• Proprietary
• Slow moving for customisations
• Inflexible - vendor knows best
• Slow turn-around times for quotes, maintenance and delivery
WARWICK MANUFACTURING GROUP CASE STUDY

- A department of the University of Warwick
- Working with JLR, Tata Motors, Tata Steel, GlaxoSmithKlyne, Airbus, Arup, Rolls-Royce, Siemens, Astra Zenica, BAE Systems
- Undergrad, Postgrad and Research programmes
- Work with SMEs
- Broad automotive research topics, including EV and ADAS
HARDWARE APPROACH

- NI PXI with EtherCAT IO for expansion system
- Bench top power analyser - serial
- Custom PDU
- CANOpen for dyno inverter control and for cell services
- CAN for DUT inverter comms
- EtherCAT for test inverter comms
- Patch panel mode
INTUITIVE TEST SEQUENCING AND SCRIPTING

- No need for high-level programming experience.
- Predefined test-steps for configuration and test profile creation.
- Integrated Python scripting tool allows new steps to be created for applying calculations to channels, importing new file formats and other requirements.
DYNAMIC USER INTERFACE

• Configure and save user interface in test.
• Create profiles specific to your requirements.
• No need to restart test.
SOFTWARE APPROACH

Communication buses are examples. In reality, customer can select an appropriate set of buses for their HW.
TEMPORAL VIEW OF COMPONENTS – AXIS

(every single iteration of PCL (typically 1kHz) or decimation thereof)

- **Fixed IO**
- **Required plugins (replace only)**
- **Predefined CAN interface (customer)**
- **User/Calculated Channels**
- **Custom plugins (add or replace)**
- **Management / Safety model**
- **Alarms/Logging**
- **Dyno Inverter setpoint control**
- **DUT Inverter setpoint control**
- **Custom Model(s)**

*Management and Safety model functionally may be separated*
POTENTIAL APPLICATIONS FOR SYSTEM

- Any standard testing of electric machines (DC motors, induction motors, PM motors brushless DC, IPM, axial-flux,...).

- Characterize noise and vibrations and run efficiency map testing as well as drive cycle behaviour for e-machines in electrified propulsion systems.
POSSIBLE IMPROVEMENTS / CHANGES?

Automated Server-Side Data Standardization and Analysis

DataFinder Server

Analysis Server
POSSIBLE IMPROVEMENTS / CHANGES?

NI ATE Core Configurations

RM-26999 – Power Measurements Conditioner
NI POWER ELECTRONICS

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WRAP UP

- Flexibility is key to testing electric vehicles.
- EV test requires different disciplines to work together.
- A modular approach is flexible and extensible.
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