SOLUTION BROCHURE

Electric Vehicle Battery Pack and Module Test

Performance Characterization, Durability Testing, and Lifetime Testing

Contents

Battery Test System Overview

The Battery Test System (BTS) is designed to optimize battery test workflows and give test teams the access and flexibility they need to respond to rapidly changing test requirements. The BTS includes features such as a flexible system architecture; an open interface with a hardware abstraction layer for adding devices; system simulation to validate test sequences with equipment models; and enterprise data- and systems-management tools for large-scale deployments. The BTS can help you stay ahead of requirements churn and drive-test efficiency improvements to accelerate schedules, increase test coverage and quality, and reduce the total cost of test.

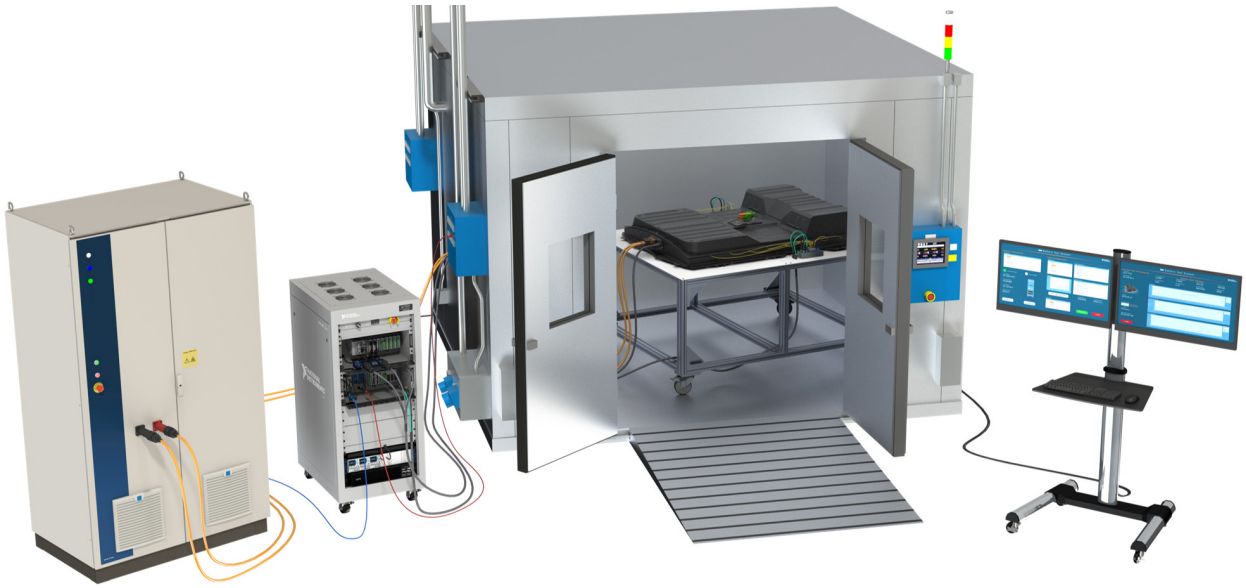

Figure 1. The NI Battery Test System

BTS Advantages

Reduce Test Development and Configuration Times

- Easily make modifications and upgrades with flexible hardware and software configuration and NI's modular I/O and signal-conditioning approach
- Simplify test definition and customization with standardized interfaces between application (VeriStand) and test-management (TestStand) software
- Take advantage of standardized cycler, chamber, and other device/instrument interfaces with a hardware abstraction layer to rapidly switch out equipment

Increase Test Efficiency

- Optimize equipment configuration, test monitoring, data collection, and results-reporting with integrated enterprise-level system and data management options
- Turn data into actionable insight with built-in data analysis capabilities

Streamline the Buying Process

- Configure a preintegrated system that's been validated, manufactured, and tested by NI
- Utilize a single point of contact for battery test and measurement across labs and test installations

Battery Pack and Module Test Challenges

The battery pack is the single most costly electric vehicle (EV) component and has the largest impact on design and performance (size, weight, acceleration, range, charge time, and vehicle life). It also carries a high warranty-liability risk due to its potential for catastrophic field events and high replacement cost in the event of a recall. Getting the design right is critical to avoiding these issues and ensuring program success. EV battery teams must minimize cost while maximizing performance, and do it on aggressive timelines while ensuring the pack operates and fails safely every time, all the time, over the life of the vehicle and beyond. EV battery teams must validate their design against requirements for:

- Safety—The battery must be safe under all specified operating conditions. If it does fail, it must fail safely in all failure modes, whether due to a manufacturing defect such as a faulty cell or weak weld, or a crash that punctures or otherwise damages the battery.
- Performance—The battery must meet performance design goals such as charge time, peak energy transfer rates, and thermal stability.
- Longevity—The battery must maintain a certain capacity over a certain number of cycles defined by expected usage behavior and vehicle life (for example, 80 percent of original capacity remaining after 2,500 charge cycles).

Inherent EV battery characteristics can create challenges in finding an effective test strategy to validate designs:

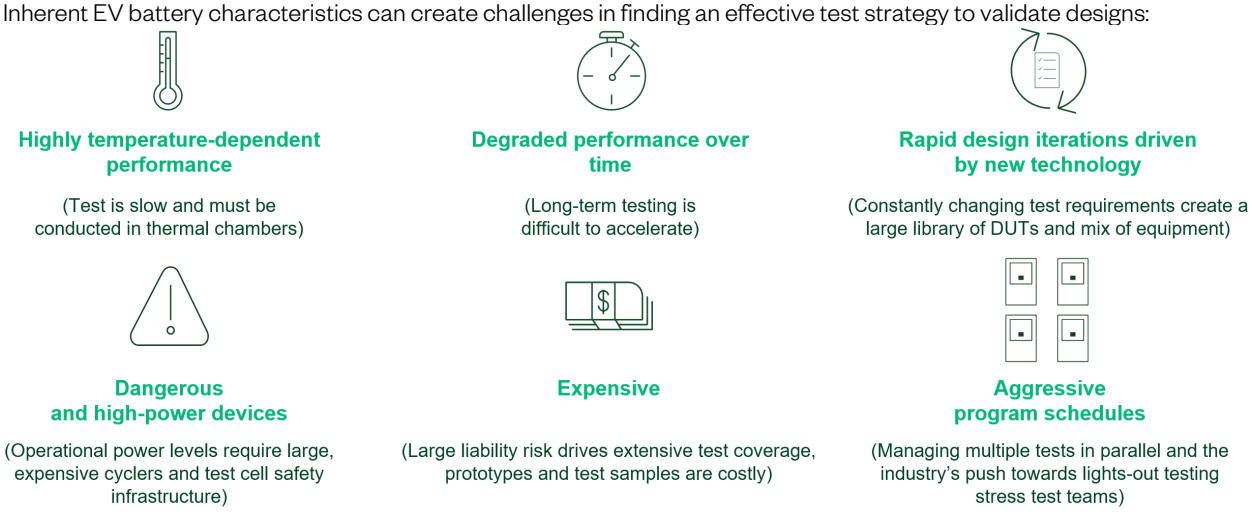

Figure 2. EV Battery Characteristics Lead to Testing Challenges

These EV battery characteristics may find you running long-term, difficult-to-accelerate tests on duplicate test cells. These challenges extend to managing the systems and the data they produce. Rapidly changing test requirements make traditional, vendor-dependent test systems time-to-market and additional-expense risks. And test teams want to own test-system hardware and software changes.

While SAE, ISO, IEC, and UL standards provide test-requirement baselines, battery test teams augment them to ensure that designs are validated properly.

Common design requirements:	Common test methods:
Capacity	Coulomb counting
Current collector performance	Drive-cycle testing
Internal resistance	Protection system test
Fuse reliability and accuracy	Temperature cycling
Cooling system performance	Hipot and pressure decay
Functional operation	Functional test

Test-System Design

Battery test needs are defined by characteristics of the DUT and test-requester (design team) requirements. The BTS is designed to address these needs in the context of battery-testing workflows.

Test Characteristics

- Potential for very long test times
- Rapidly changing DUTs and test requirements
- Large, parallel deployments
- Industry push towards lights-out testing

Test Needs

- Stable, sometimes month-long test executions
- True multi-up testing support
- Quick adaptation to changing test requirements and DUT interfaces
- System-management and software-deployment tools
- Data management, analysis, and reporting tools

Design Implications

- Real-time OS and infrastructure options for system stability (uninterruptible power)
- Ability to independently start/stop executions running concurrently
- Hardware abstraction layer with third-party tool support
- Platform-based system designed for flexibility and expansion
- Tight integration with enterprise tools for test, data, and systems management

Figure 3. Test needs and characteristics drive battery test-system design.

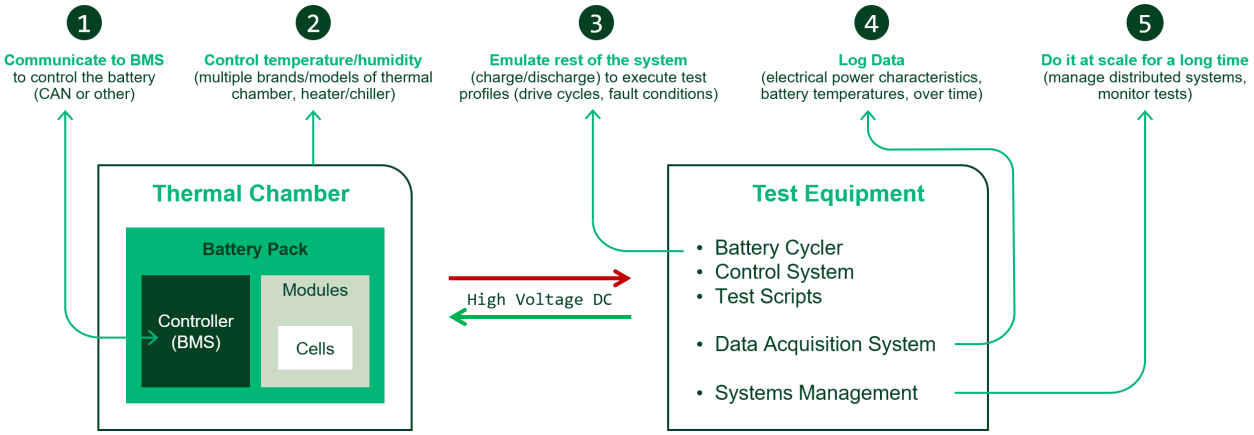

Figure 4. High-Level EV Battery Test Workflow

System Details

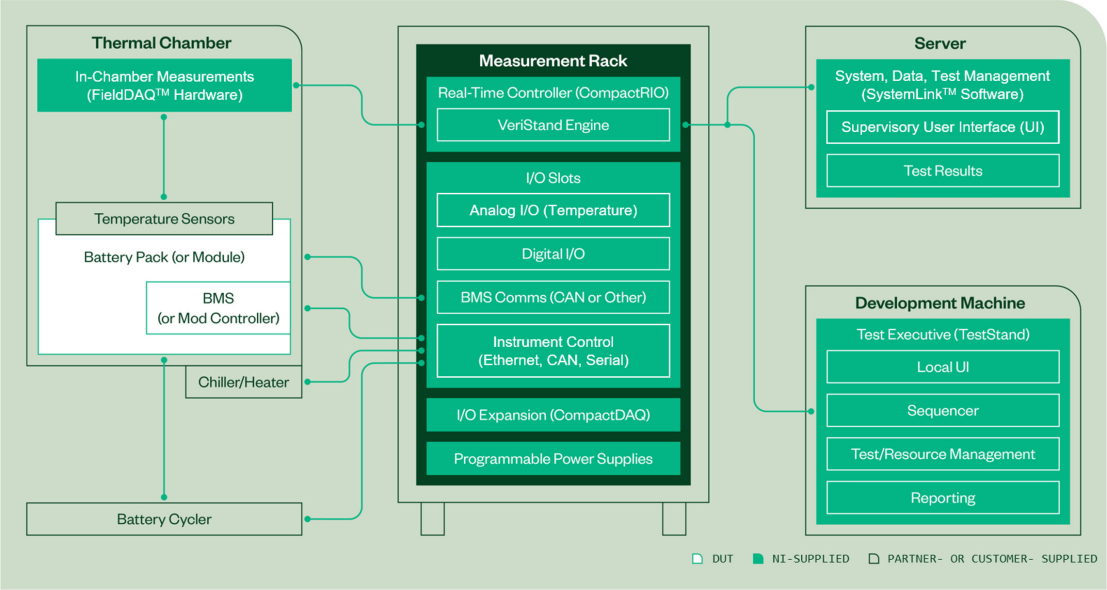

Figure 5. Battery Test Station System Diagram

BTS Design Benefits

Flexible System Architecture

- *Aliases and channel mapping*: Easily switch out equipment without modifying the rest of the application using the flexible system configuration for simplified test setup and customization.
- *Modular and expandable C Series I/O*: Expand channel-counts and add mixed measurements.

Third-Party Equipment Integration

- *Instrument add-ons*: Utilize the hardware abstraction layer and configuration-based communications and control setup for battery cyclers, thermal chambers, and chillers.

In-Chamber Measurements

- *Rugged, synchronized, IP-rated FieldDAQ™ DAQ devices:* Move instrumentation inside a thermal chamber, reduce cabling, and accelerate test setup (keep the instrument DUT rig separate from your test station).

Long-Term Lossless Logging

- *TestStand real-time sequences*: Integrate VeriStand and TestStand for test scripting and long-term test stability.
- *Data logger and black box recorder*: Never lose data. Capture and learn from critical events.

System Simulation

- *VeriStand DUT and equipment models:* Decouple software development from hardware availability to validate test scripts without equipment to speed up development and derisk system deployments.

Integrated Systems and Data Management

- *SystemLink™ software custom devices*: Publish tags, data logs, and test reports to see system status and reporting anywhere, anytime.
- *SystemLink software systems/data/test management tools:* Implement an enterprise-level management solution to increase operational efficiency and decrease system commissioning time with mass system configuration, remote monitoring, and test databases.

Battery Test System Software

BTS software combines VeriStand and TestStand with battery-test-specific plug-ins, device drivers, and analysis/test IP in the Battery Test System Software Toolkit. You can integrate it with SystemLink software for enterprise-level system and data management.

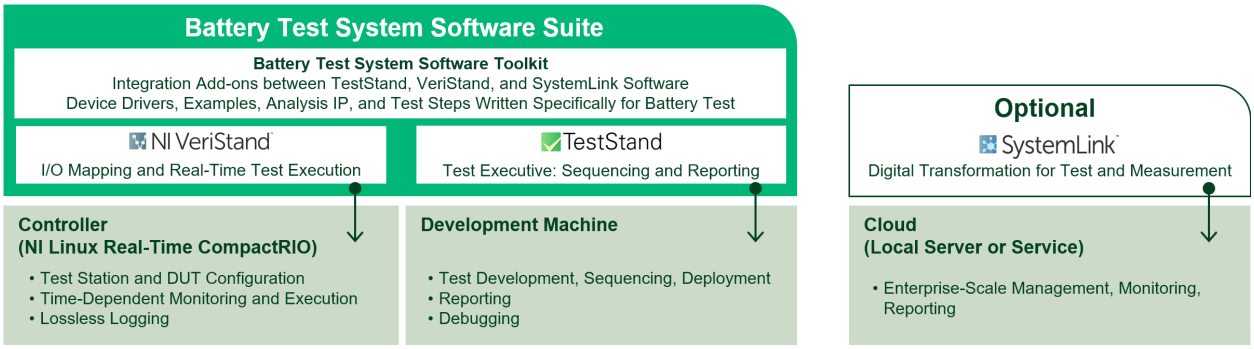

Figure 6. The Battery Test System Software Suite provides a flexible and scalable high-performance battery test application architecture.

Real-Time Test Software—VeriStand

VeriStand provides a real-time engine for I/O configuration, model integration, instrument and device integration, and lossless long-term logging.

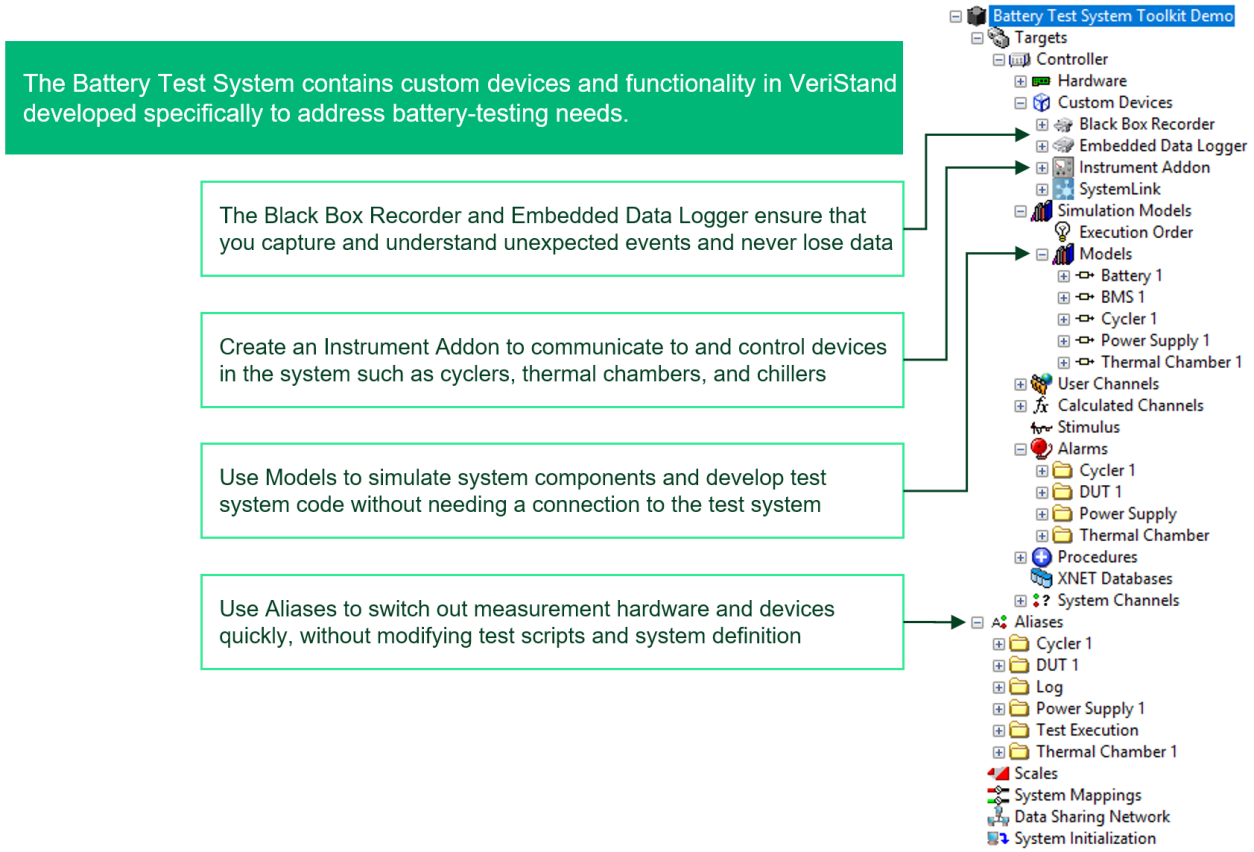

Figure 7. The VeriStand System Definition File contains the BTS system configuration information.

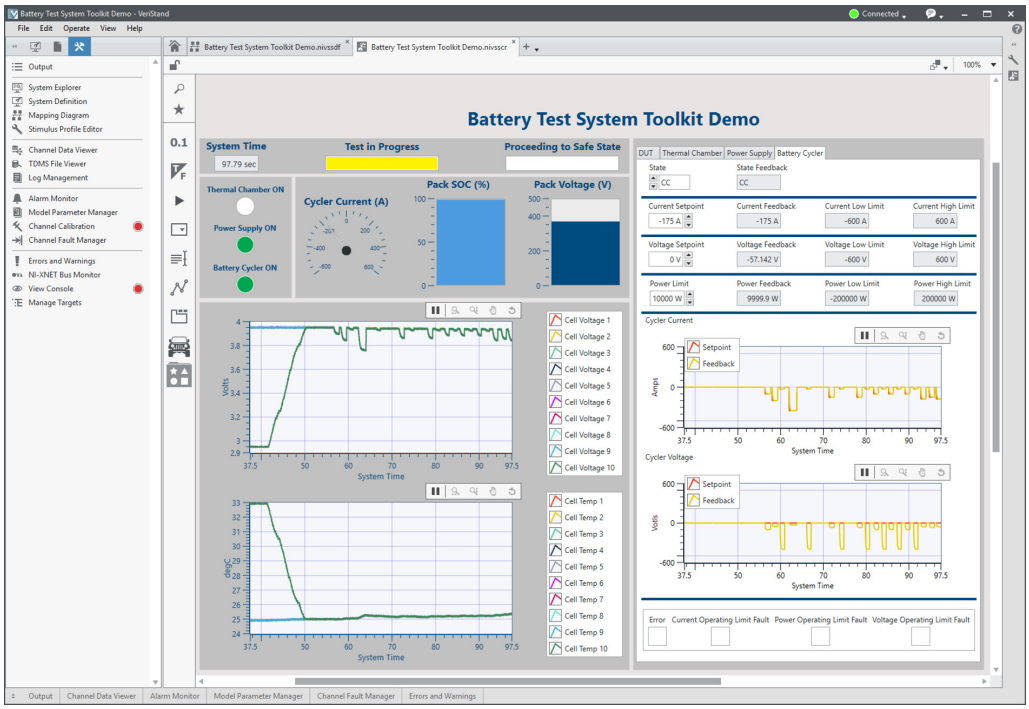

Figure 8. Example VeriStand screen showing battery test information and connected device status.

Test-Sequencing and Test-Management Executive Software—TestStand

TestStand provides rich automated test development, sequencing, and reporting functionality. Use TestStand to develop test scripts that call into and interact with VeriStand to command equipment to put the DUT in the right state to test, execute profiles, and report test data.

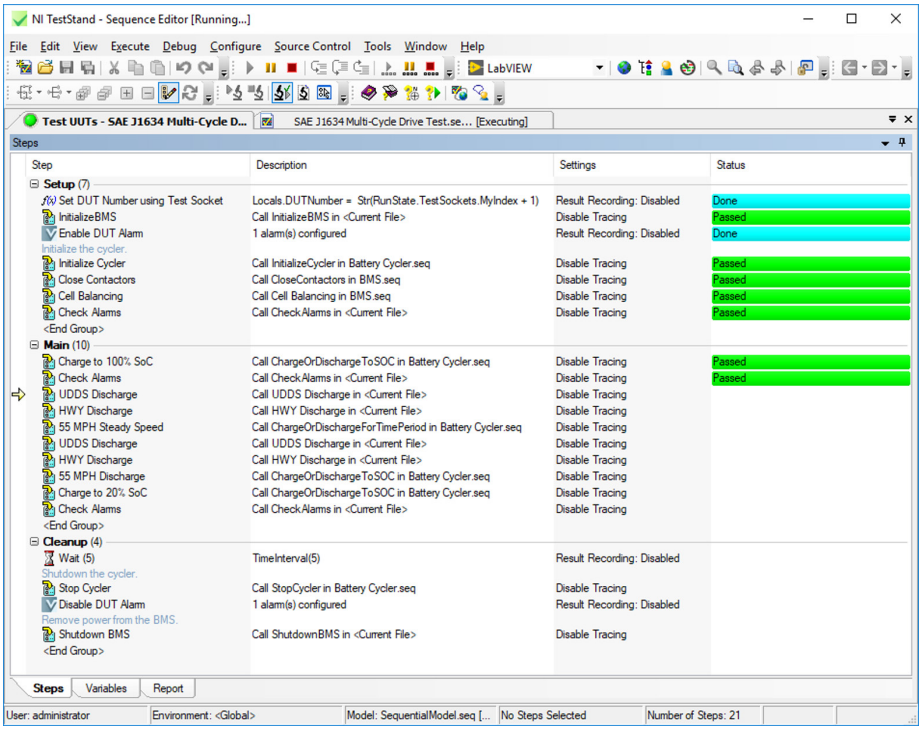

Figure 9. Example TestStand Sequence for an SAE J1634 Multicycle Drive Profile Test

Test-System and Asset-Management Software—SystemLink Software

SystemLink software (optional) provides enterprise-level data, systems, and test management tools that scale with test infrastructure size and complexity. You can extend SystemLink software with LabVIEW WebVIs for remote system access and status from anywhere via a customizable web interface. With SystemLink software, you can implement standardized and consolidated data storage/search/access and reporting that is customized for your unique circumstances.

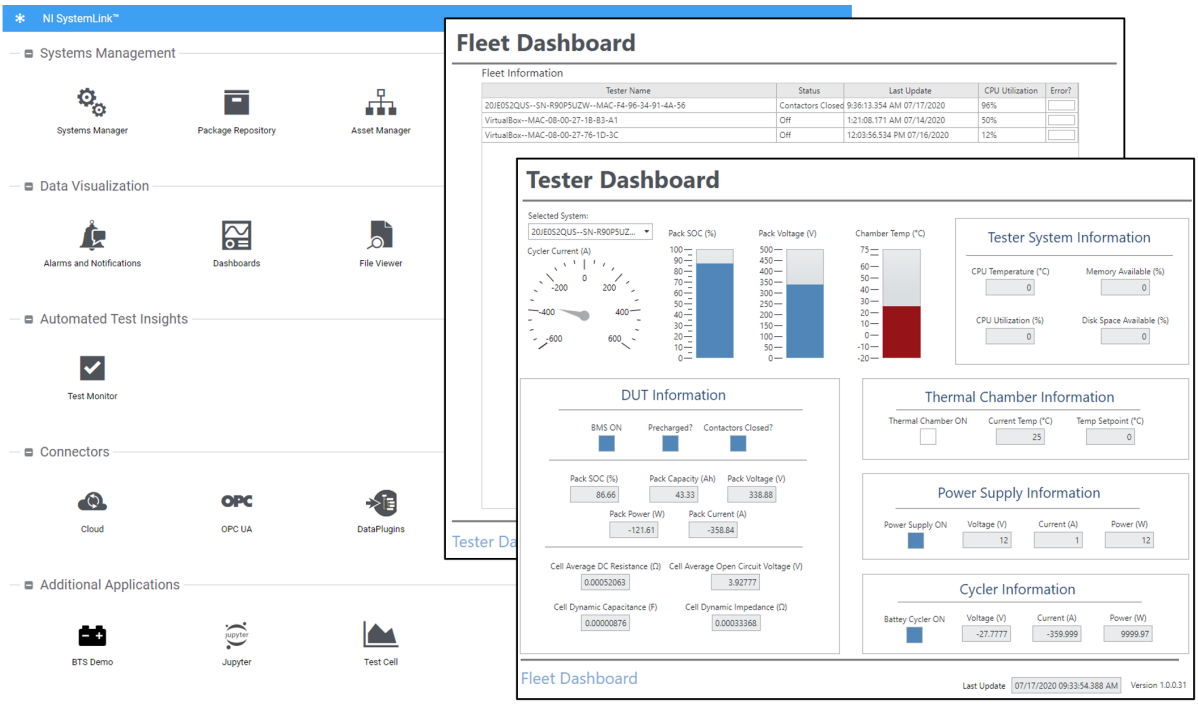

Figure 10. Use SystemLink software to manage systems, view tag data in real time, view archived reports, monitor tests, interact with custom dashboards, and more.

Battery Test System Software Toolkit

The Battery Test System Software Toolkit provides add-ons, device drivers, examples, and analysis IP that integrate VeriStand, TestStand, and SystemLink software into a workflow purpose-built for EV battery test.

Figure 11. Custom Battery Test System Deployment UI Example Based on LabVIEW

Measurement Rack and I/O

The BTS measurement rack is designed for modularity and expansion, to connect to a variety of different equipment and to the enterprise, and to run long-term automated tests.

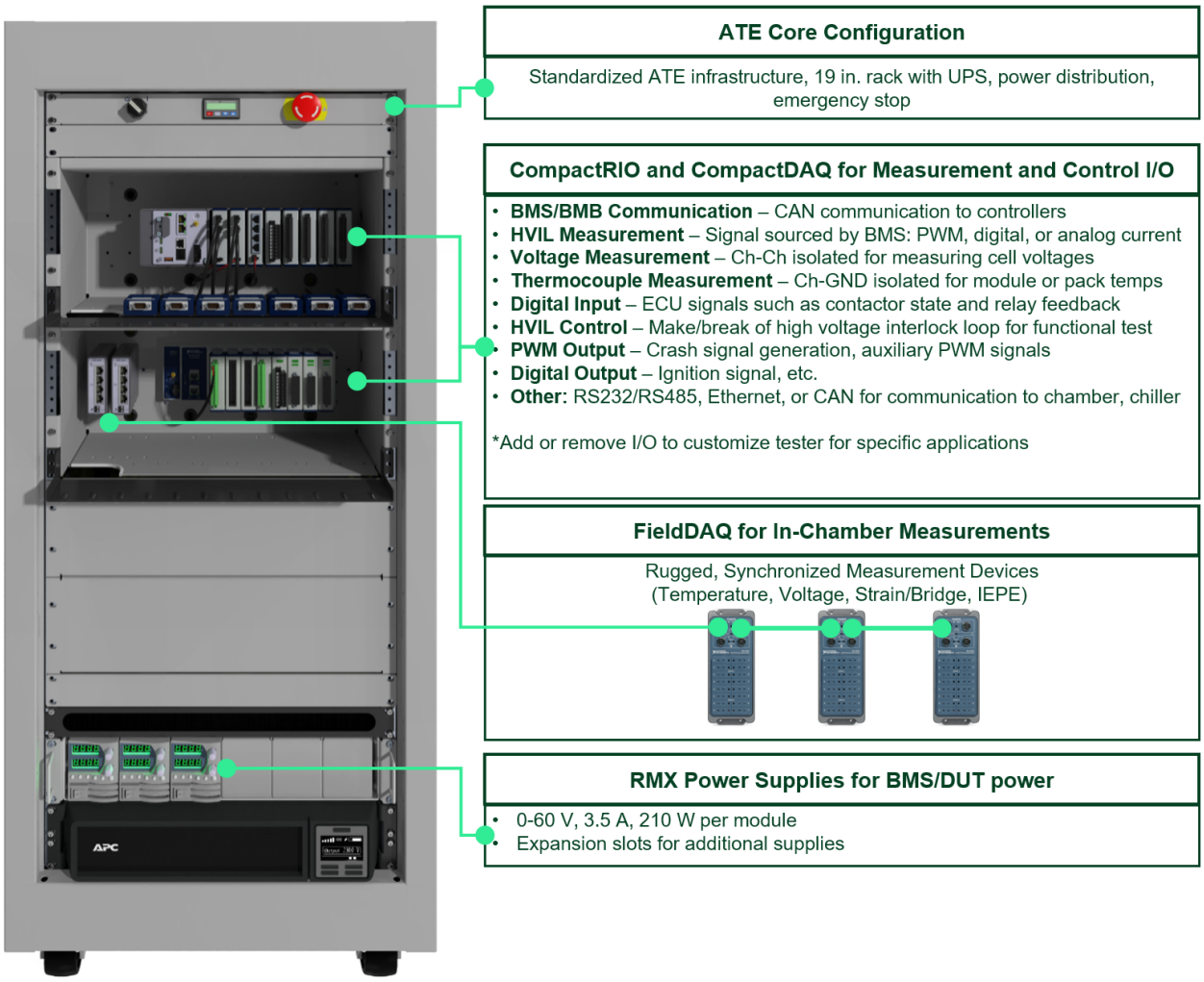

Figure 12. Battery Test System Measurement Rack

Measurement Rack Configuration Options

Scale your test system by changing measurement mix and channel counts to meet evolving test requirements. Common system configuration considerations based on application I/O set and requirements include:

- Voltage input (range versus density)
- Temperature measurements (isolation versus density versus remote I/O)
- HVIL signal type (digital input, PWM input, current input)
- DIO (range versus density)

BTS Standard Configuration

- ATE Core Rack
  - 24U, 19 in. Equipment Rack
  - 120 V/240 V UPS
  - Internal Power and Network Distribution
  - Emergency Power-Off Circuitry with External Interface
- cRIO-9047—1.60 GHz Quad-Core RT System Controller
- cRIO-9805—4-Port 802.1AS Time-Sensitive Networking (TSN) Ethernet Switch
- 8-Channel Analog Input (Emergency Power-Off and 12 V Monitoring)
- Two CAN HS/FD or LS/FT interfaces
- One 0-60 V DC output (DUT supply voltage)
- BTS Software Suite
- Basic Services Package

Add-On	Usage
0-60 V DC Output	Redundant supply circuits on the DUT
CAN Outputs	Additional test hardware or DUT interface
RS232 or RS485	Temperature chambers, chillers, cyclers, or other test hardware interface
GPIB	Temperature chambers, chillers, cyclers, or other test hardware interface
Cell Voltage	Direct, individual, stacked cell voltage module measurement (up to 250 V)
Module Voltage	Direct, individual module voltage pack measurement (up to 600 V)
Local Temperature	Rack-based thermocouple measurement
Remote Temperature	In-chamber thermocouple measurement
Digital I/O	ECU signal emulation DI/DO/PWM options
HVIL Monitoring	Existing HVIL DI/PWM/analog monitoring options
Relay Output	HVIL control

Test System Control and Measurement—CompactRIO

CompactRIO systems contain a processor running the NI Linux Real-Time OS and a user-programmable FPGA, and are populated with conditioned I/O modules from NI or third-party vendors.

Figure 13. An 8-Slot CompactRIO system is at the heart of the Battery Test System measurement rack.

CompactRIO systems include:

- An NI Linux Real-Time OS for lossless logging, deterministic control, and reliable operation
- C Series I/O for flexible reconfigurable measurements
- TSN communications for synchronizing distributed systems and measurements

I/O Expansion—CompactDAQ

CompactDAQ chassis control the timing, synchronization, and data transfer between NI C Series I/O modules and an external host.

Figure 14. CompactDAQ chassis with C Series I/O modules add I/O to the system.

With a CompactDAQ chassis, you can:

- Expand your channel count with a mix of deterministic, modular C Series I/O
- Achieve automatic submillisecond triggering and synchronization using TSN ethernet with an integrated network switch for easy daisy-chaining

In-Chamber Measurements—FieldDAQ Hardware

Use a rugged, IP-rated FieldDAQ device to move instrumentation inside a thermal chamber, reduce cabling, and accelerate test setup (instrument the DUT rig separately from the test station).

FieldDAQ hardware provides:

- A single set of cables (power and data) to pass out (FieldDAQ devices can be daisy-chained)
- Rugged I/O (fanless, IP65/IP67, -40 °C to 85 °C, 10 g vibration, and 100 g shock)
- Temperature, voltage, strain/bridge, and sound and vibration (IEPE) input options

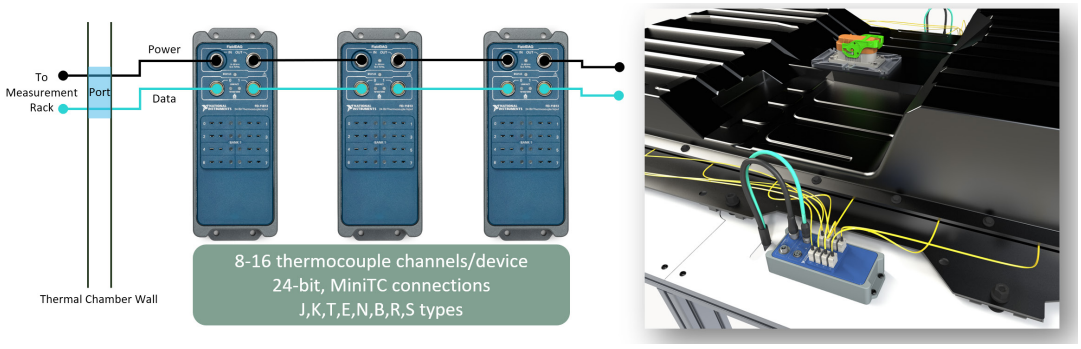

Figure 15. You can use FieldDAQ devices such as the FD-11613 (thermocouple input) to instrument battery modules and packs inside the thermal chamber, reducing setup time and cabling.

Battery Cycler Integration

The BTS can integrate battery cyclers from any vendor. Because the BTS was deisgned to be cycler-agnostic through an instrument abstraction layer, you easily can swap cycler vendors and models as needed without modifying the rest of your test system. Being able to quickly configure a new test setup with different equipment is key to meeting aggressive test schedules for rapidly changing designs, especially if your lab is handling concurrent test for multiple programs with different battery voltage levels and design goals.

You can integrate a battery cycler with the BTS through *instrument add-ons*, a hardware abstraction layer with configuration-based communications and control setup for any device. Easily swap out different cyclers through *aliases and channel-mapping* to keep the rest of your software architecture the same while interfacing to different equipment through instrument add-ons:

- Interface to most cyclers (CAN/Ethernet) through a configuration-based interface
- Interface with nonstandard cyclers by creating an interface with a VeriStand plug-in (custom device)

Figure 16. Integrate Battery Cyclers from Any Supplier

Battery Test Workflow

NI developed the BTS to optimize EV battery test workflows and give test teams the access and flexibility they need to overcome challenges and respond to rapidly changing test requirements. The BTS can help you accelerate schedules and reduce total cost of test by staying ahead of requirements churn and increasing test coverage through test efficiency improvements.

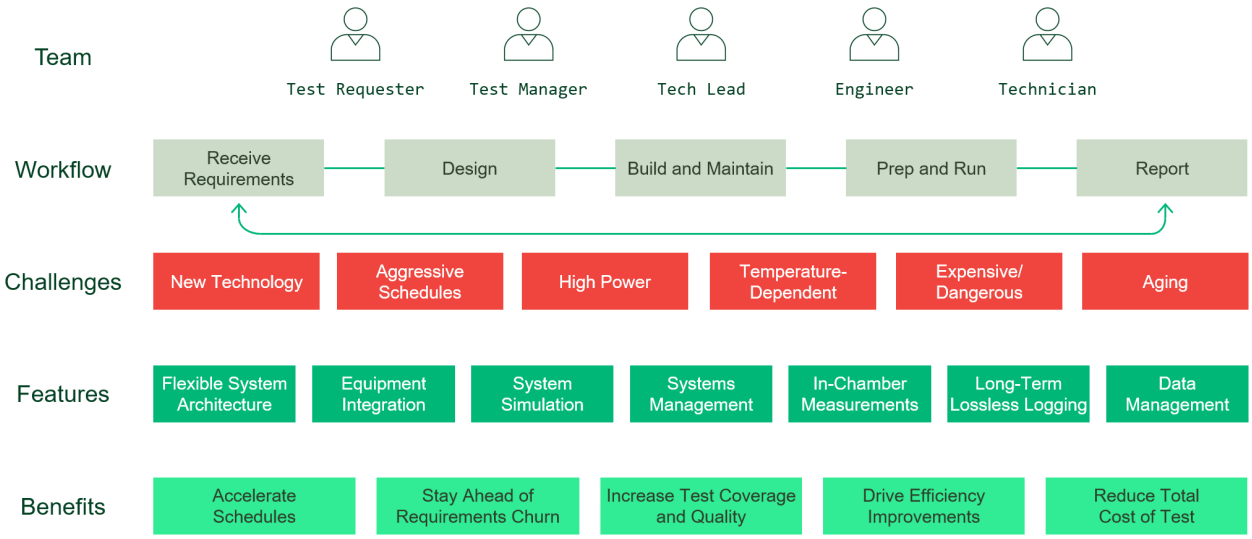

Figure 17. BTS Features Mapped to Team-Member Tasks in a General Battery Test Workflow

BTS Features

Flexible System Architecture

The BTS provides a flexible test architecture—you can customize its foundation and expand upon it with NI, NI Partner, and customer products to meet specific program and test-application requirements.
The combination of open customizable software and modular extensible hardware means that you can adapt to changing requirements with high test system reuse and shorter development times:

- Quickly connect and reconfigure systems (I/O type and count, equipment changes)
- Reuse test scripts defined with hardware aliases
- Extend software as needed while leveraging a common test architecture

Open, Customizable Software

- Extend BTS-provided I/O configuration, hardware abstraction layers, and device connectivity with VeriStand custom devices and LabVIEW
- Extend BTS-provided test scripting and reporting capabilities with custom step types and process models in TestStand
- Extend BTS-provided SystemLink software connectivity for systems management with custom dashboard and reporting LabVIEW WebVIs

Modular, Extensible Hardware

- Mix and match powerful CompactRIO controllers with modular C Series I/O to meet specific test I/O requirements and scale with test application needs. Customize I/O functionality with onboard custom signal processing, data reduction, or specific condition- and logic-alarming intelligence
- Easily scale BTS I/O for larger systems by adding one or more automatically synchronized TSN CompactDAQ chassis for additional C Series I/O
- Add rugged distributed I/O using TSN synchronization to take in-chamber measurements

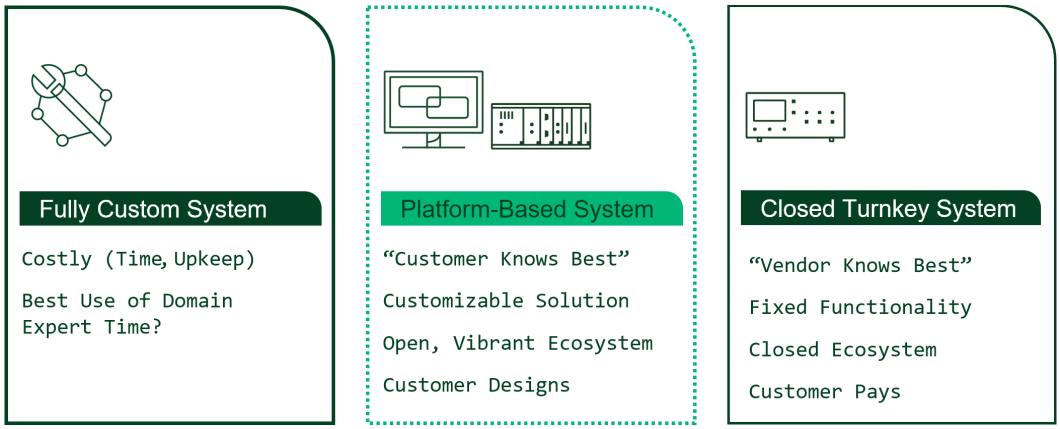

Figure 18. A platform-based system focuses on your needs, not what a vendor says that you need.

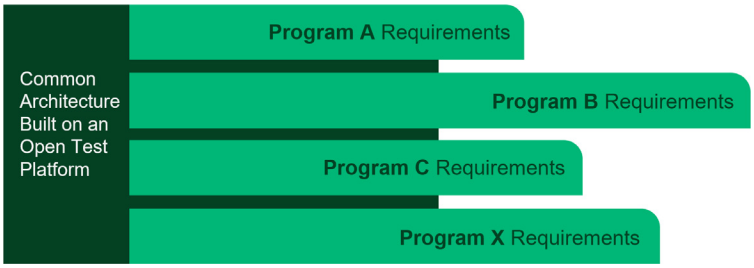

Figure 19. Utilize BTS common test architecture to leverage investment across multiple programs/projects/devices and shorten testing cycles.

Equipment Integration (Cycler, Chamber, Chiller)

The BTS makes it simple to support a variety of equipment brands and models. Instrument add-ons and I/O aliases offer a hardware abstraction layer between the equipment and the BTS software, making it easy to switch out battery cyclers and other instrumentation and quickly reconfigure a test station for different requirements with new equipment.

Instrument Add-ons

Instrument add-ons provide a standardized way to talk to any instrument that has a supported communication protocol: CAN or LIN through the NI-XNET interface, or serial, GPIB, and User Datagram Protocol (Standard Commands for Programmable Instruments or custom) through the NI-VISA interface.

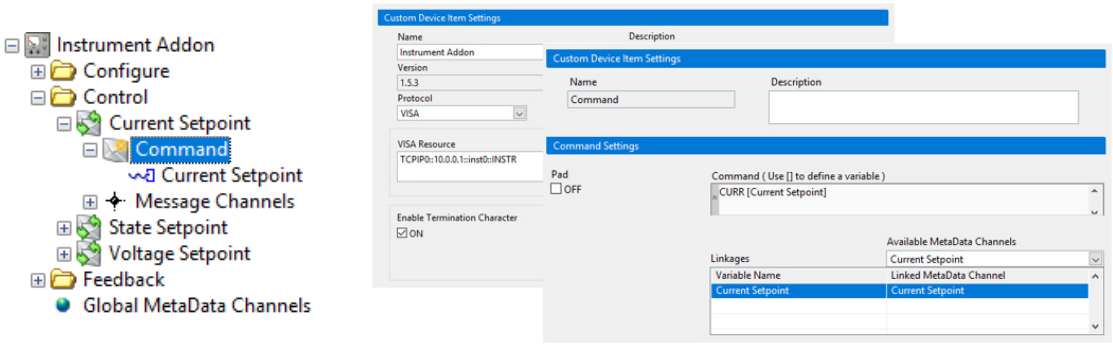

Figure 20. Configure the protocol and command set for a particular instrument in the Instrument Addon VeriStand custom step settings.

Once configured, you can use the custom step in any test station configuration utilizing that instrument simply by loading the correct instrument add-on. This way, you can write and maintain your own library of instrument plug-ins to support your unique mix of equipment.

I/O Channel Aliases

With I/O channel aliases, you can reuse tests even when equipment and test station configurations change.

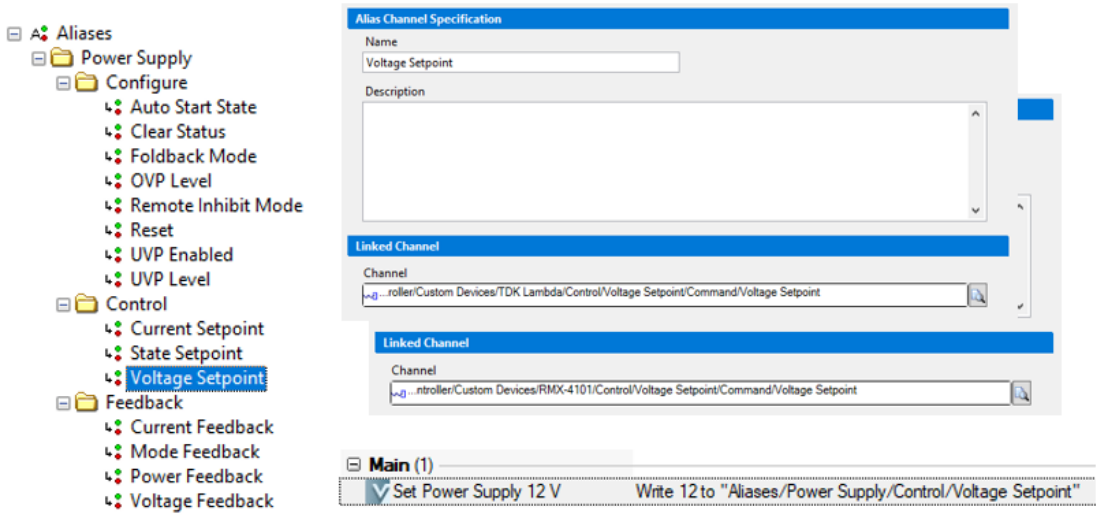

Figure 21. You can standardize on a common convention for I/O channel-naming and then link physical I/O channels to aliases. This makes it easy to swap out physical I/O channels and equipment.

Using both instrument add-ons and I/O aliases together, you quickly can reconfigure systems and effectively manage a mix of constantly changing equipment brands and models.

System Simulation

With the BTS, you can use models to simulate devices and test equipment to write and validate test sequences and software without the hardware present. Easily switch between model-based simulation and real equipment by switching projects.

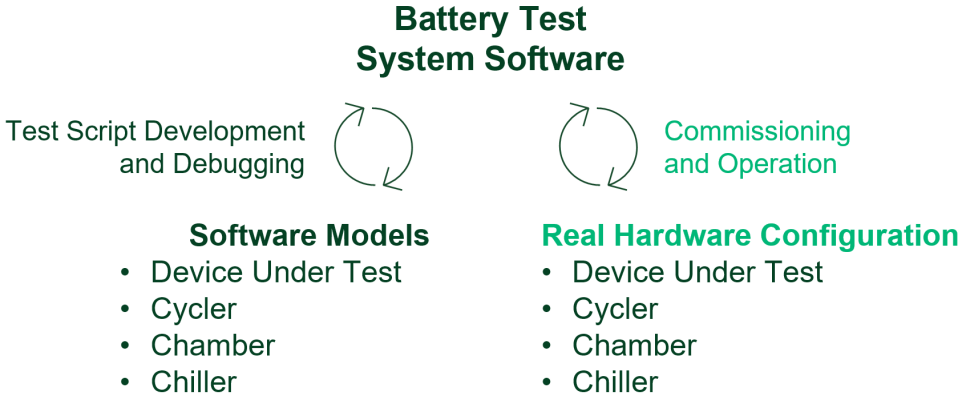

Figure 22. Utilize system simulation to accelerate testing by decoupling development from hardware availability and derisking deployments.

Utilize system simulation to:

- Shorten schedules by removing critical path dependencies
- Incorporate remote teams and enhanced collaboration
- Reduce test and equipment risk and expensive debugging after deployment with test sequence testing in simulation
-

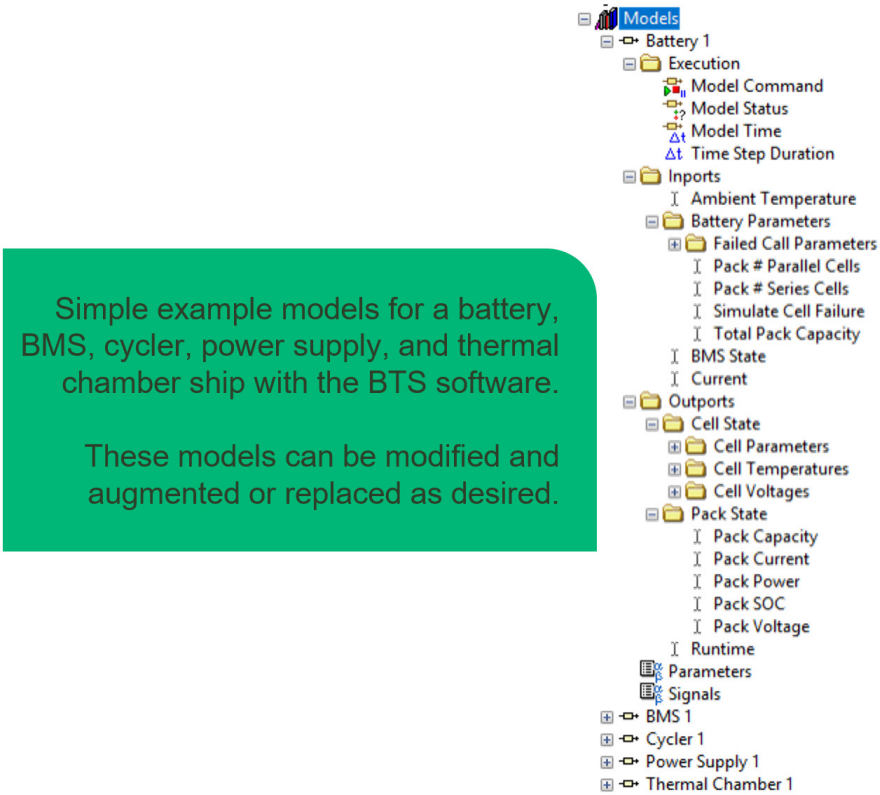

Figure 23. Battery Model Items Shown in the VeriStand System Definition File

Lossless Long-Term Logging

Few things are more frustrating than invalidating a months-long test because your system crashes or your data logging setup fails. With expensive and time-consuming tests in the test-schedule critical path, you need to make the most of every test opportunity. That's why the BTS includes reliable and robust data logging tools: You'll never lose test data over the course of long-term testing. BTS data logging capabilities are built on the VeriStand real-time engine running on the NI Linux Real-Time CompactRIO controller for long-term stability. An IT-mandated system update or development computer crash won't interrupt your tests.

The BTS is purpose-built for long-term testing and data acquisition and includes configurable logging with file-spanning and the ability for onboard/offboard storage to ensure data files are properly saved and organized according to your needs.

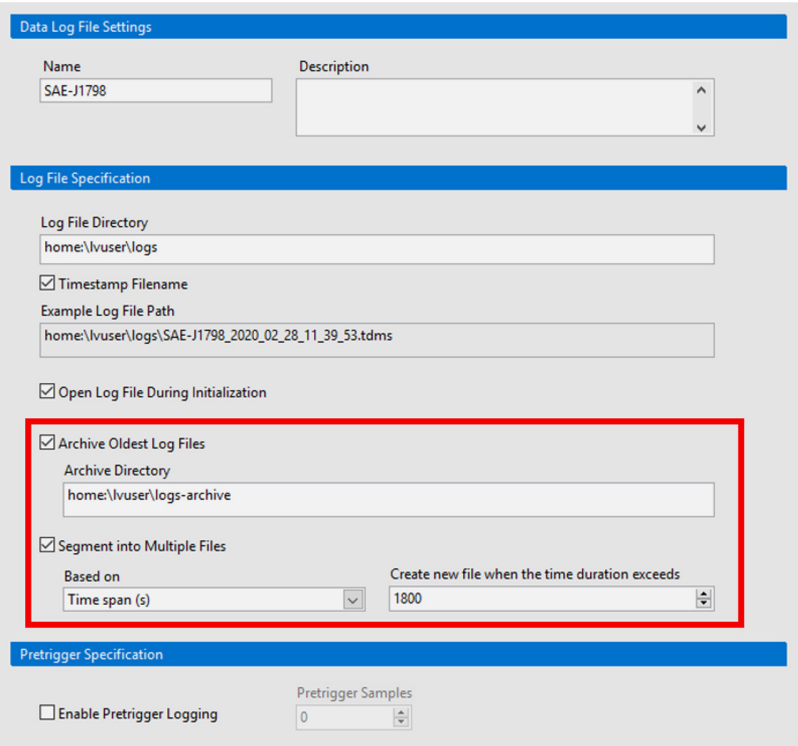

Figure 24. Data Logger Archiving and File-Spanning Settings

The BTS also includes a black box recorder that captures high-resolution data around critical events for further analysis and interpretation. Using the black box recorder, you can log all VeriStand channels to file on a trigger command and use buffers to collect and report data both before and after a trigger event.

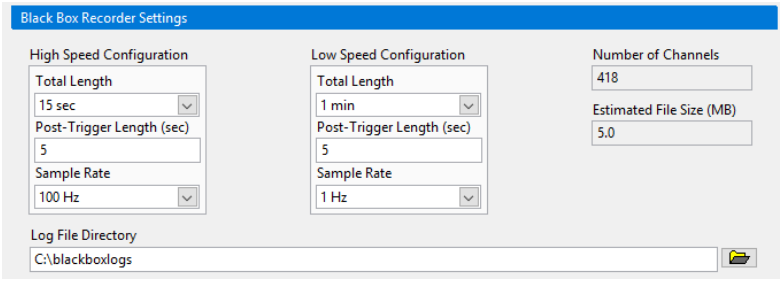

Figure 25. Black Box Recorder Settings

Large-Scale Test Deployment Management

SystemLink software offers a way to manage tasks such as software deployment, device configuration, test/station monitoring, and data management/visualization. It delivers improvements in operational efficiency and productivity by providing you with a centralized network-based management interface for connected devices, software, and data. The benefits of SystemLink software scale with the size of your test installations and number of devices at different test stages.

Figure 26. Use BTS-SystemLink software integration to effectively manage large-scale battery test deployments.

SystemLink software features for large-scale test-system deployments include:

- A supervisory UI for remote monitoring and alarming
  - Manage multiple distributed test stations
  - Monitor system status and test state, health, utilization, and data trending
- A test-results database
  - Automatically prepare your data from multiple sources for queries and analysis
  - Quickly access and search measurement data across test systems
  - Intelligently analyze files and generate reports automatically
- Systems management capabilities
  - Efficiently replicate and deploy test systems
  - Centrally manage distribution software
  - Perform remote device-configuration and diagnostics
  - Manage system performance health with alarms management, notifications, and calibration reporting

System Integration

System Customization

The BTS is extremely extensible and customizable. Let's discover and explore your possibilities with NI or an NI Partner.

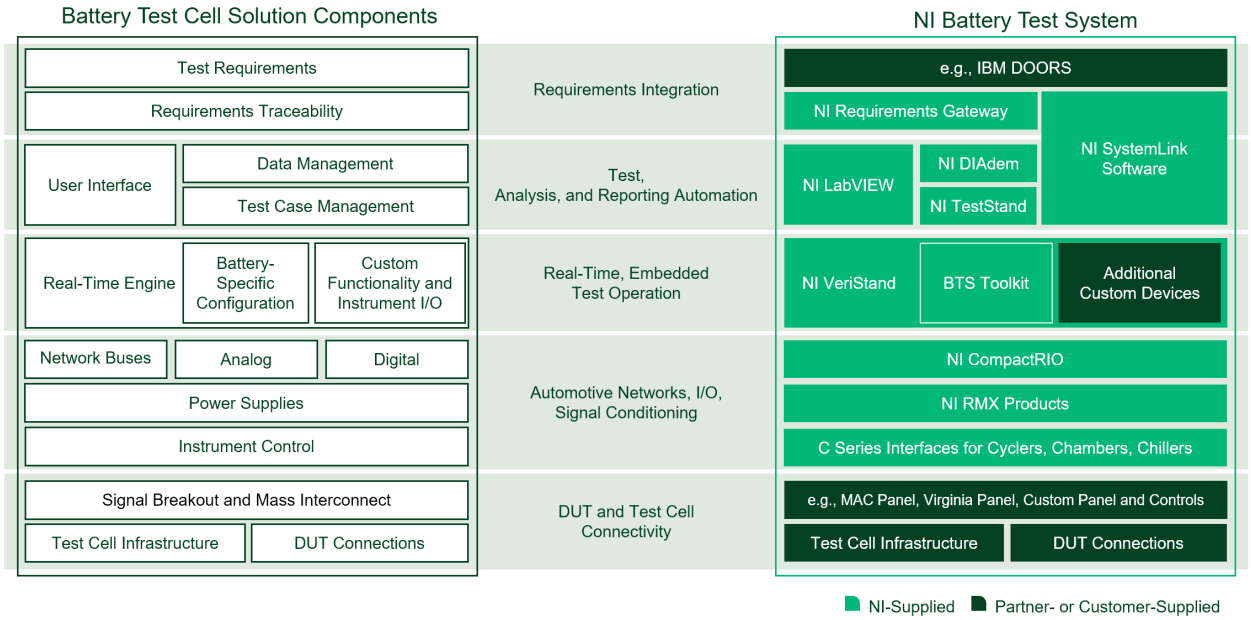

Figure 27. Customize the Battery Test System to Meet Your Specific Application Requirements

Facility/Lab Design Considerations

Connect with NI and our NI Partners early in your design process to learn about test equipment considerations when building out your lab or facility—whether it is a new building, a lab expansion leveraging existing equipment, or a containerized test solution.

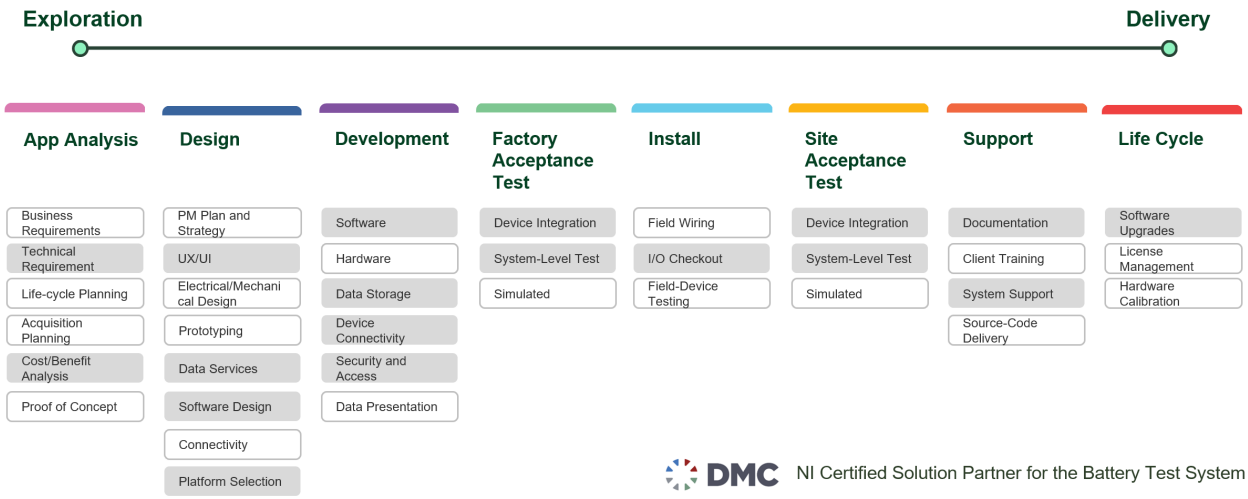

Figure 28. Work with NI and our NI Partners to Design and Implement Test Solutions

Services and Support

You expect NI systems to help you solve some of the most challenging engineering problems—and you can expect the same level of capability with our services. With every BTS deployment, NI partners with you to determine the level of service that best meets your application needs and ensures your long-term success.

Obtain peace of mind through support from BTS experts to accompany your in-house maintenance operations. Three years of our Basic Service Program is included with every BTS, with the option to reduce or increase the program duration.

	BASIC	CUSTOM
Software Support Access updates and bug fixes	Software-Update Access	We Work with You to Define the Scope on a Case-by-Case Basis
Repair and Replacement Minimize downtime	Replacement in Three to Five Days	
Technical Support Resolve issues quickly	Technical Support 8x5	
Field and Remote Services Enjoy a fixed maintenance cost		
Life-Cycle Management Mitigate obsolescence risk	Standard Product Notifications	
On-Demand Training[1] Ensure user success	Online Operator and Maintenance Training	

	OPTIONS
Calibration Obtain quality measurements and traceability	Laboratory Calibration On-site Calibration Calibration Replacement
Bring-Up Assistance Achieve hassle-free commissioning	On-site or Remote Tester Bring-Up
Training[1] Ensure user success	Private Classroom (On-Site or Virtual) for Operator and Maintenance Training
Professional Services	Integration Services, Technology Refresh, Upgrade Assistance Consulting Services Resident Engineer

[1] Available December 2020

Next Steps

Contact your account manager or NI at (888) 280-7645 or info@ni.com to schedule your:

- Consultation
- System Configuration
- Demonstration