Smart-Pack-for-Advanced-Research-and-Control (SPARC)

UNIVERSITY OF
South Carolina

Molinaroli College of
Engineering and Computing

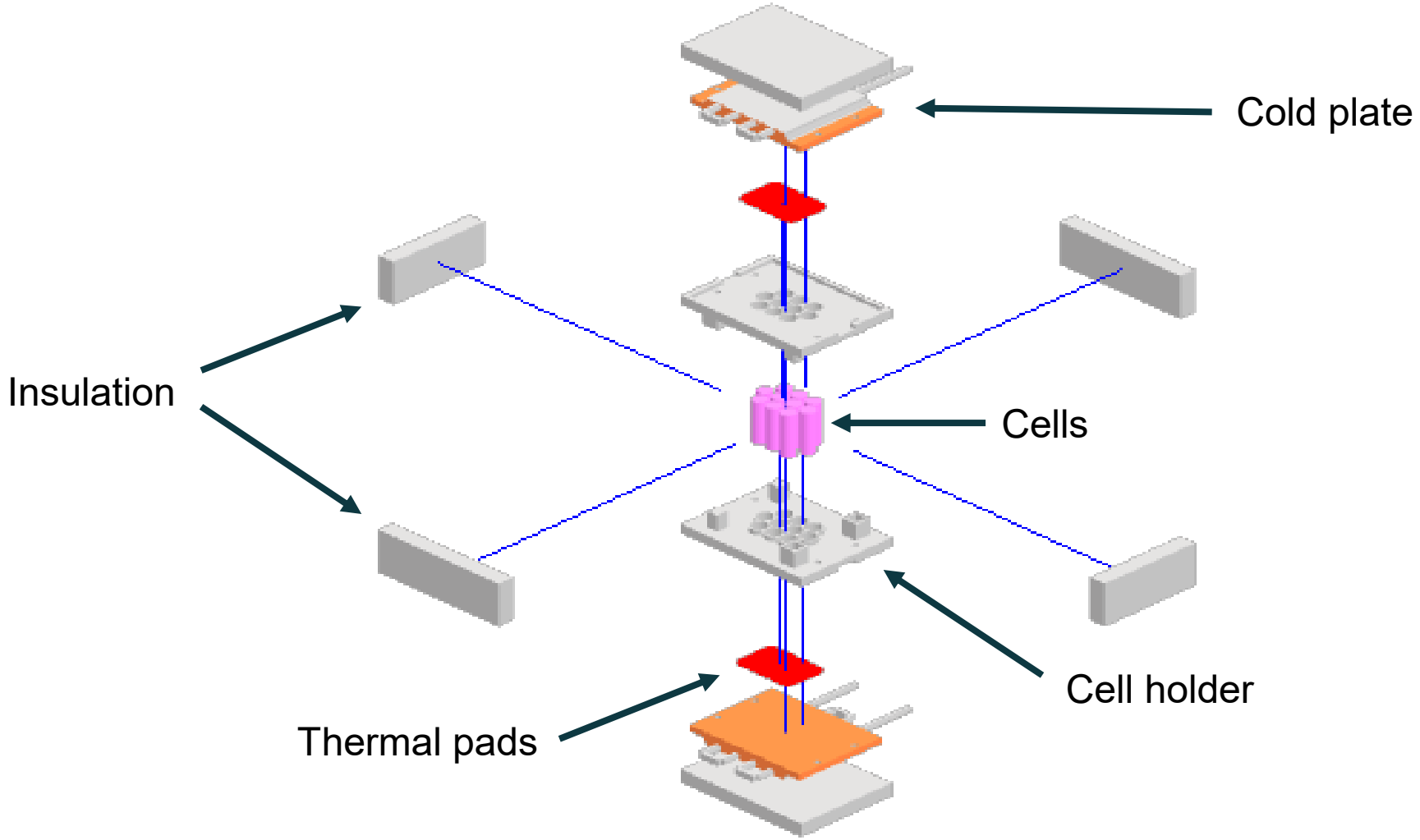
Why Develop a Modular, Sensor-Rich Battery System?

- Supports Next-Generation Energy Storage
  - Enables research on distributed energy systems and high-performance battery management
  - Facilitates scalability for a wide range of power applications
- Enhances Digital Twin Development
  - Real-time, high-fidelity data streams enable dynamic model validation and predictive analytics
  - Integrated sensors allow continuous updates to electrochemical, thermal, and mechanical models
- Enables Flexible and Configurable Testing
  - Modular 42V (10S1P) design allows for series/parallel stacking to replicate different battery pack architectures
  - Supports multiple cell sizes and chemistries (e.g., 18650, 21700, NMC, LFP) for diverse application studiesImproves
- Advanced Battery Control and Monitoring
  - High-resolution BMS with CompactDAQ integration enables real-time state estimation and anomaly detection
  - Adaptive energy management through advanced control strategies

Why Not Just Buy a Battery Pack?

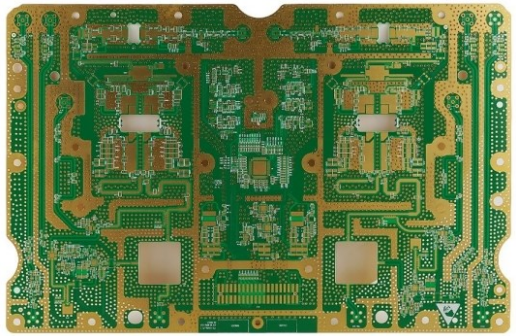
- It’s Not That Simple
  - Off-the-shelf battery packs are designed for consumer or industrial use, not for research and experimentation
  - Most commercial packs come with proprietary BMS systems that restrict access to raw data, limiting the ability to monitor and analyze cell-level behavior
- Limited Experimental Flexibility
  - Research often requires testing individual cells and full packs under identical conditions, which isn’t possible with third-party pack builders
  - By sourcing cells from a single batch, researchers can compare degradation, thermal response, and electrochemical performance at both cell and pack levels
  - Pack design constraints in commercial solutions prevent studies on alternative cooling strategies, advanced sensing, and new control architectures
- Need for Custom Sensing and Instrumentation
  - Commercial battery packs do not support high-resolution instrumentation, such as differential voltage sensing, strain monitoring, and acoustic emissions
  - In research, advanced sensing capabilities are critical for developing and validating digital twins, studying failure mechanisms, and improving predictive modeling
  - Custom-built packs allow for direct integration with external control and data acquisition systems, ensuring researchers have full control over charging, discharging, and monitoring parameters

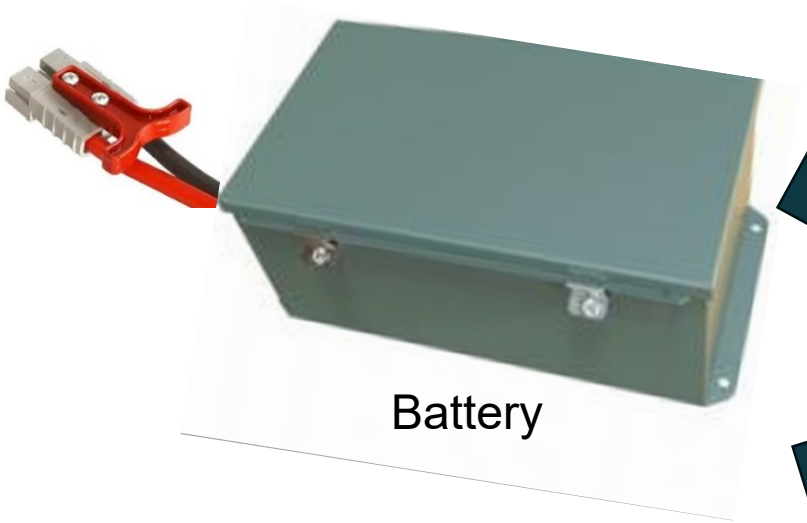
What Will the Battery Module look like?



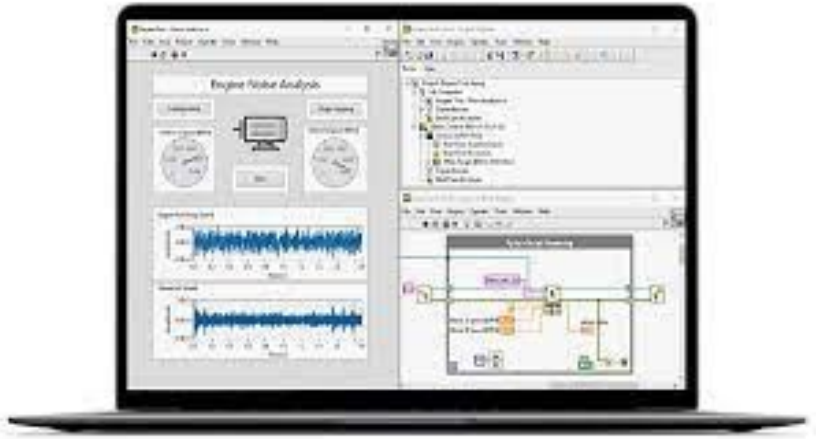
What Will the BMS Look Like?

BMS Control Board





Battery



cDAQ based DAQ

Cost:

- $20,000 fully-instrumented
- $10,000 typical deployment
- $4,000 minimal viable

What Features will the Pack Have

Comprehensive Sensing Capabilities

- Voltage Monitoring – Individual cell voltages and differential voltage across each cell for precise state-of-charge (SOC) estimation
- Temperature Sensors – Each cell will have dedicated temperature monitoring, ensuring thermal stability and safety
- Current Sensors – High-resolution current measurement for charge/discharge tracking and efficiency analysis
- Strain Gauges – Integrated strain sensing on cells and pack components to monitor mechanical deformation and aging effects
- Acoustic Emission Sensors – Captures high-frequency signals from crack formation, gas evolution, and early failure indicators

Advanced Battery Management Features

- Cell-Level Monitoring – Every cell is individually monitored for voltage, temperature, and strain, allowing detailed analysis of cell-to-cell variations
- Cell Balancing – Passive balancing to start, ensuring even charge distribution and extending pack lifetime
- Customizable Data Sampling – Fully open data acquisition interface, allowing researchers to modify sampling rates and data logging parameters

Open-Access and Reconfigurable Design

- Fully Open Front Panel – Allows for easy access to all monitoring points, enabling rapid sensor modifications, data acquisition customization, and external integrations
- Flexible Control Integration – Can directly support adaptive BMS algorithms and digital twin updates

Thank You for Your Time

Name: Austin Downey

Title: Associate Professor

Email: austindowney@sc.edu

Lab GitHub: github.com/arts-laboratory

Molinaroli College of Engineering and Computing
UNIVERSITY OF SOUTH CAROLINA