Designing Open Architecture Hardware-in-the-Loop (HIL) Test Solutions for UAVs/Drones and Electrified Aircraft

Brent Hoerman

Senior Manager, DMC Inc.

Tom Sarfi

Business Dev. Manager, Pickering Interfaces

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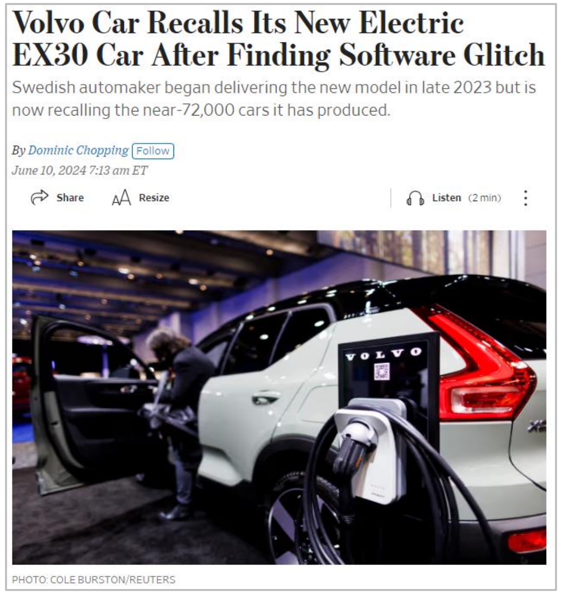
The Importance of Embedded Software Test

The impact of escaped software errors….


Airbus issues software bug alert after fatal plane crash

Glitch found in engine software requires immediate checks after issue-plagued fleet is grounded

[Source: The Guardian]


Volvo Car Recalls Its New Electric EX30 Car After Finding Software Glitch

Swedish automaker began delivering the new model in late 2023 but is now recalling the near-72,000 cars it has produced.

By Dominic Chopping Follow
June 10, 2024 7:13 am ET

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PHOTO: COLE BURSTON/REUTERS

[Source: The Wall Street Journal]


Hamilton Ventilator Recall Issued Over Risk of Sudden Failures Due to Software Defect

At least 80 complaints involving ventilator failures have been reported in relation to faulty software that prompted a recall for about 12,429 Hamilton ventilators

[Source: AboutLawsuits.com]

Financial Loss

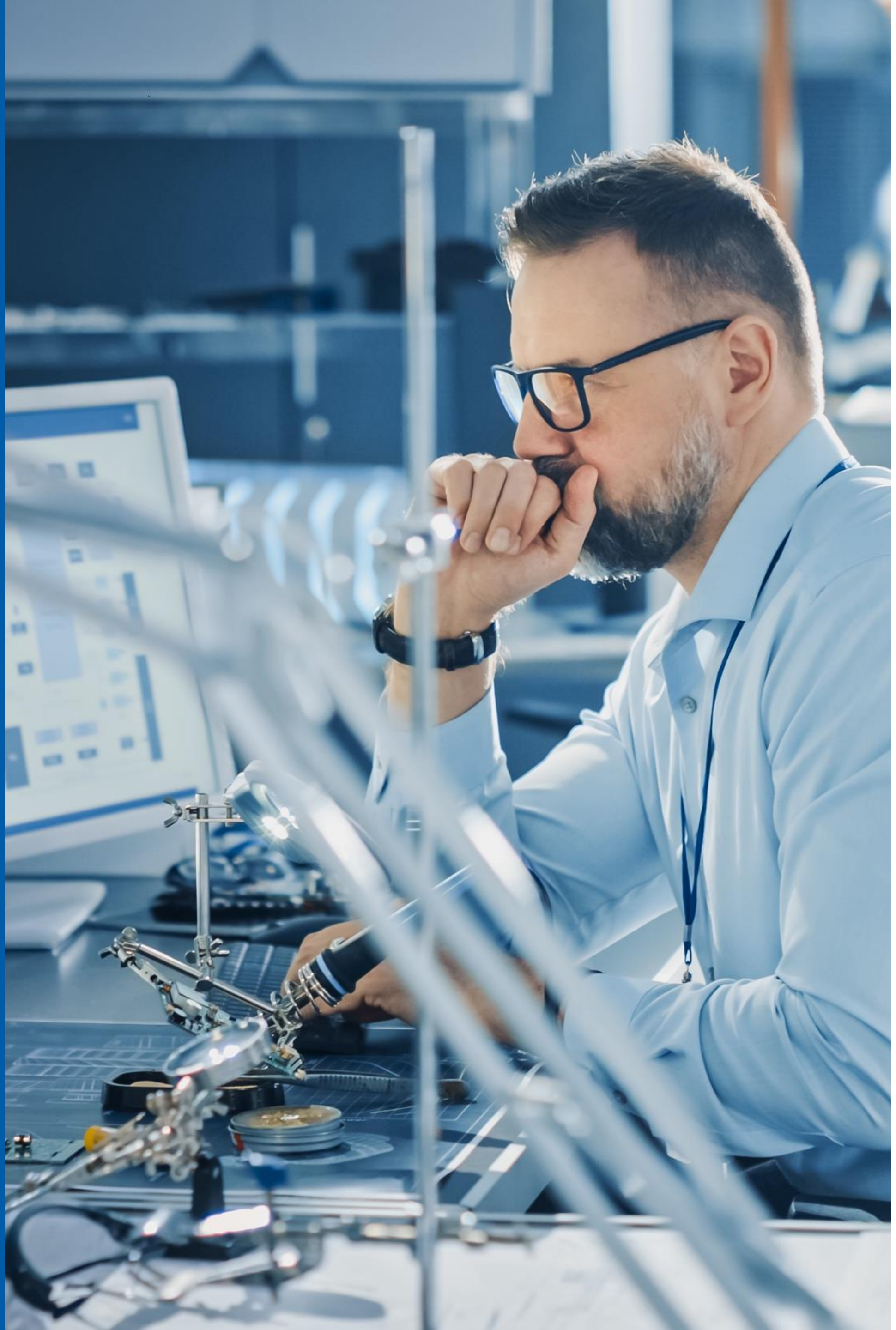
Personal Injuries

Damaged Brand

Lower Morale

What is HIL Simulation?

- A technique in which I/O from an embedded control system are connected to a tester that simulates real-world conditions
- The test system provides stimulus to the embedded system that would normally come from actual sensors/electrical signals
  - Strain gauges, thermocouples/RTDs, position sensor, encoders…
- Facilitates injection of fault conditions to confirm system response is as expected
- An efficient method of validating and verifying functionality of embedded system designs (and modifications).
  - HIL testing validates integrity of a product design
  - Functional test validates the manufacturing process



Why HIL Simulation?

- **Time is Short**: Execute a wide variety of tests quickly using simulation and models instead of setting up prototypes and physical test rigs.
- **DUTS are More Complex:** Find and fix bugs earlier in the design process to avoid defects getting out of production.
- **Budgets are Tight:** Testing on physical models is expensive and errors found early in the design process are significantly cheaper to correct.
- **Repeatability**: Test procedures can be 100% replicated to verify future control system upgrades do not impact performance.
- **Safety**: Can replicate extremes of operation without risk of damage to equipment or operators.

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HIL Testing Application Areas

- **Automotive Testing (ECUs)**
  - Advanced Driver Assistance System (ADAS)
  - Seat electronics, airbag control
  - In-car communications
- **Avionics Testing (LRUs)**
  - Flight control systems
    - Landing gear actuators
    - Flap actuators
  - Navigation systems
  - Communication systems
- **E-Mobility**
  - BMS testing
  - Electric powertrain

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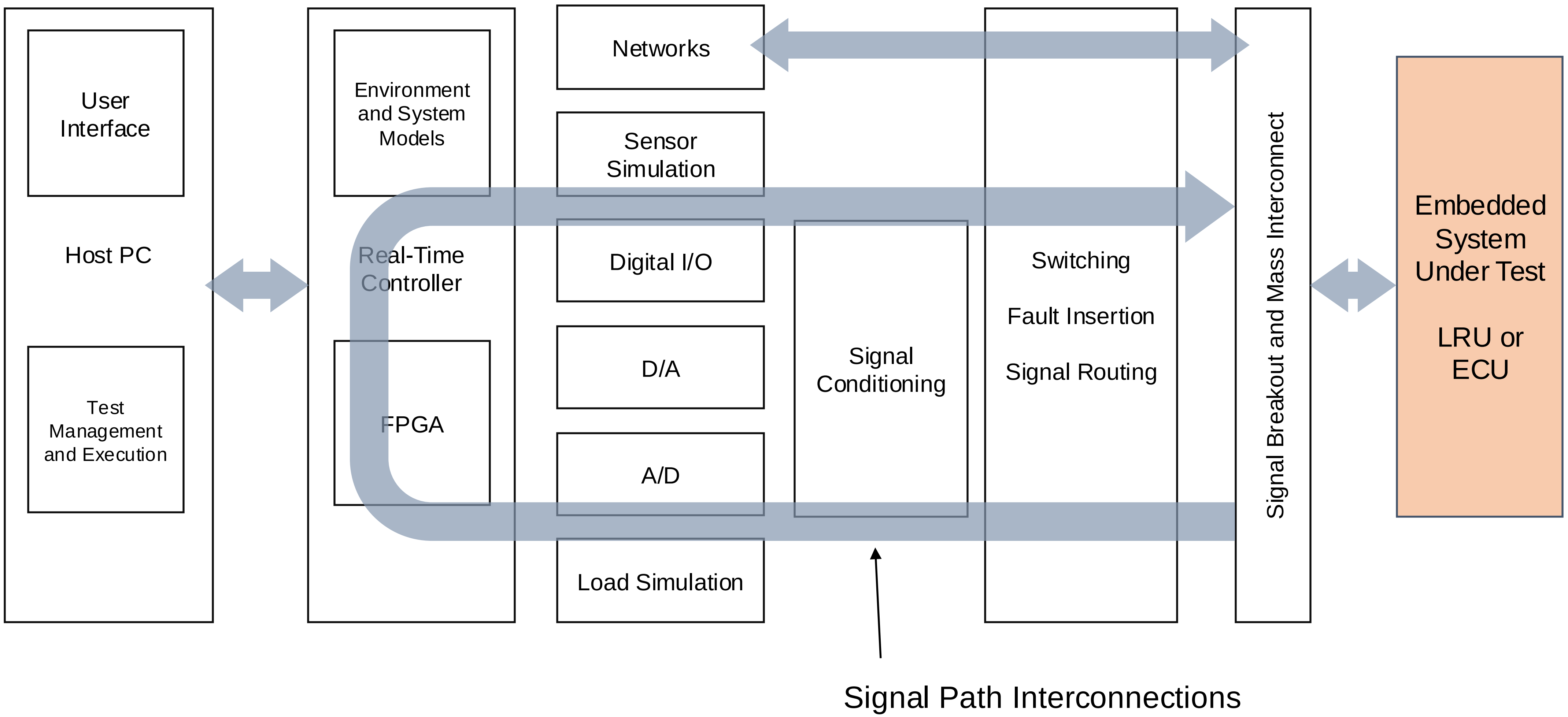
Breakdown of a HIL system



Paths to Architecting a HIL System

Operational System

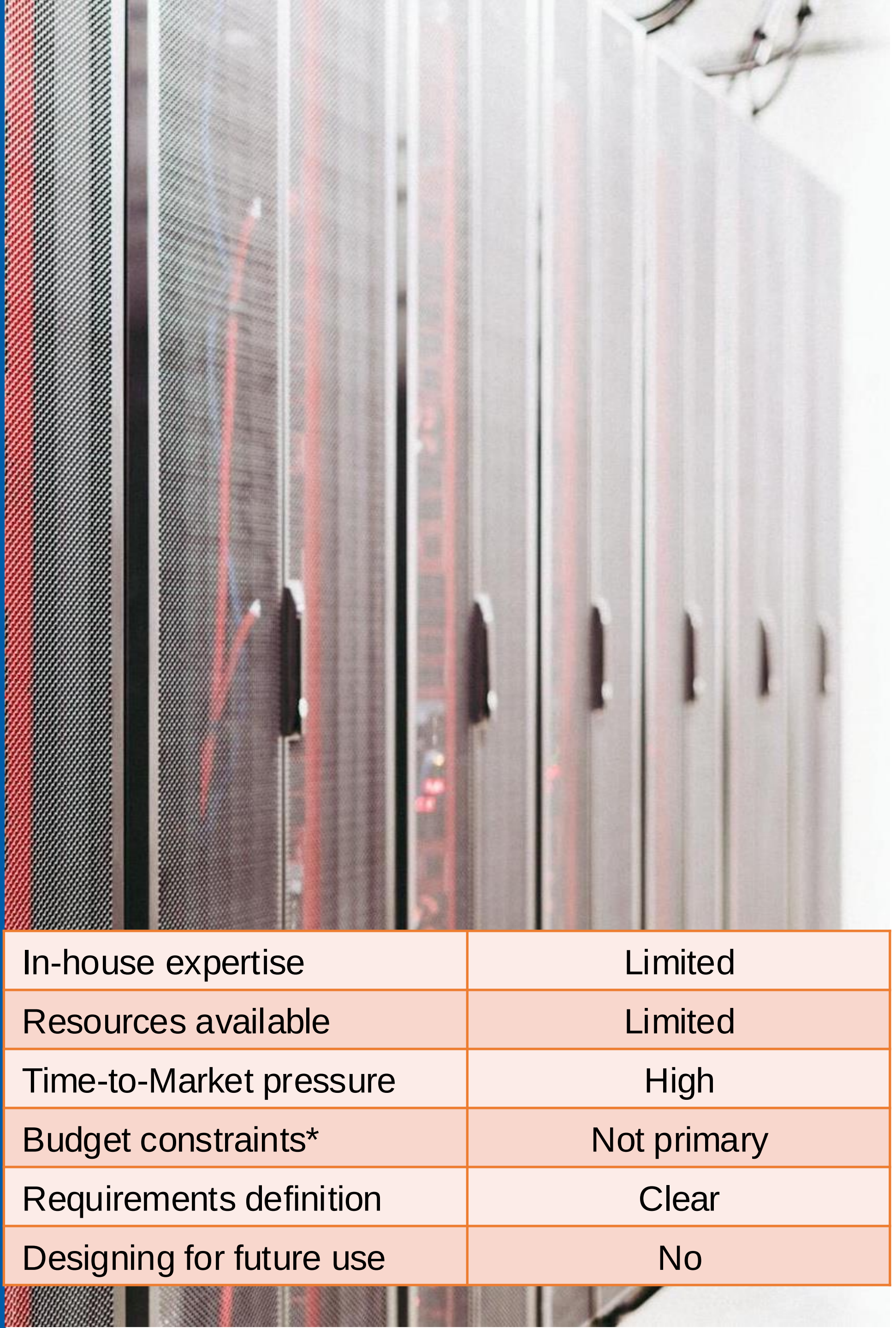
Closed Turnkey System	Purchase a vendor-defined 'black-box' HIL solution to meet your requirements	
In-house (DIY) System	Develop a custom solution using in-house resources with some COTS HW & SW	
3rd Party Collaborative System	Solutions provider and end-user work together to define system architecture	Solutions provider responsible for integration and final checkout of system

Vendor responsibility

End-user responsibility

Each path leads to the end result, but which path to choose is organization-specific

Closed Turnkey System



In-house expertise	Limited
Resources available	Limited
Time-to-Market pressure	High
Budget constraints*	Not primary
Requirements definition	Clear
Designing for future use	No

"out-of-the-box" solution

- **Advantages**
  - Minimal end-user resources needed
  - Use of proven simulation models
  - Application specific systems
- **Disadvantages**
  - No ownership of architecture
  - High software licensing fees
  - Difficult to scale as needs evolve
- **How Pickering is involved**
  - System needs expansion outside of system supplier's portfolio
  - Integrating into a closed architecture will require effort

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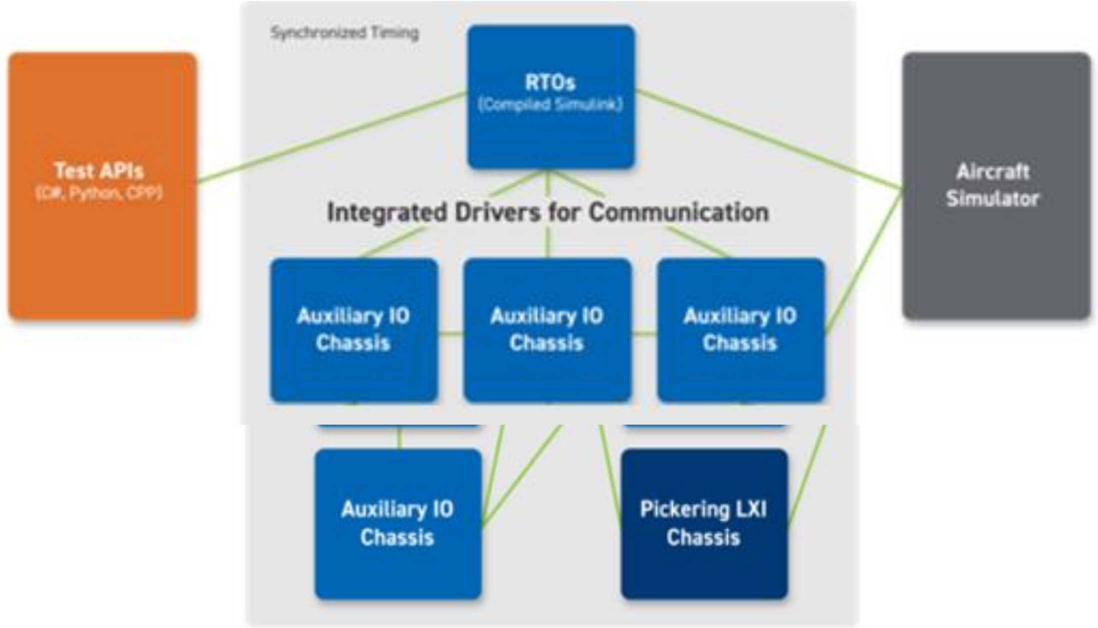
Case Study - Extending a Turnkey HIL System

- Turnkey system wasn't sufficient for evolving customer requirements.
- Needed additional I/O capability in the form of temperature, position simulation and fault insertion.
- Proposed solution would exist outside of RTOS which was not acceptable.
- End user worked with Pickering to integrate COTS chassis and I/O.
  - Open platform architecture integrated with RTOS via industry-standard LXI communication interface and driver



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In-house expertise	High
Resources available	High
Time-to-Market pressure	Limited
Budget constraints*	Considerable
Requirements definition	Fluid
Designing for future use	Likely

In-House DIY

Full control over HIL system

- **Advantages**
  - Fully owned design
  - Not bound to a single supplier
  - Ease of upgrades and expansion
- **Disadvantages**
  - In-house responsibility for design, documentation, deployment, sustainment
  - Time and resource intensive
- **How Pickering is involved:**
  - Very wide range of high-performance COTS switching, simulation, and cabling
  - Industry-standard platforms (PXI/LXI) simplify H/W and S/W integration

PXI - A Modular/Open Platform

- 3U Euro-card industry standard adapted for PC-based control of test instrumentation.
- Approximately 60 suppliers across many different technologies and application spaces:
  - Analog and Digital I/O
  - Communications busses
  - Switching and fault insertion
  - Traditional source and measurement devices
- Support of multiple OSs, including real-time, and support for commonly used APIs.
- Continuously evolving specification with backward compatibility.

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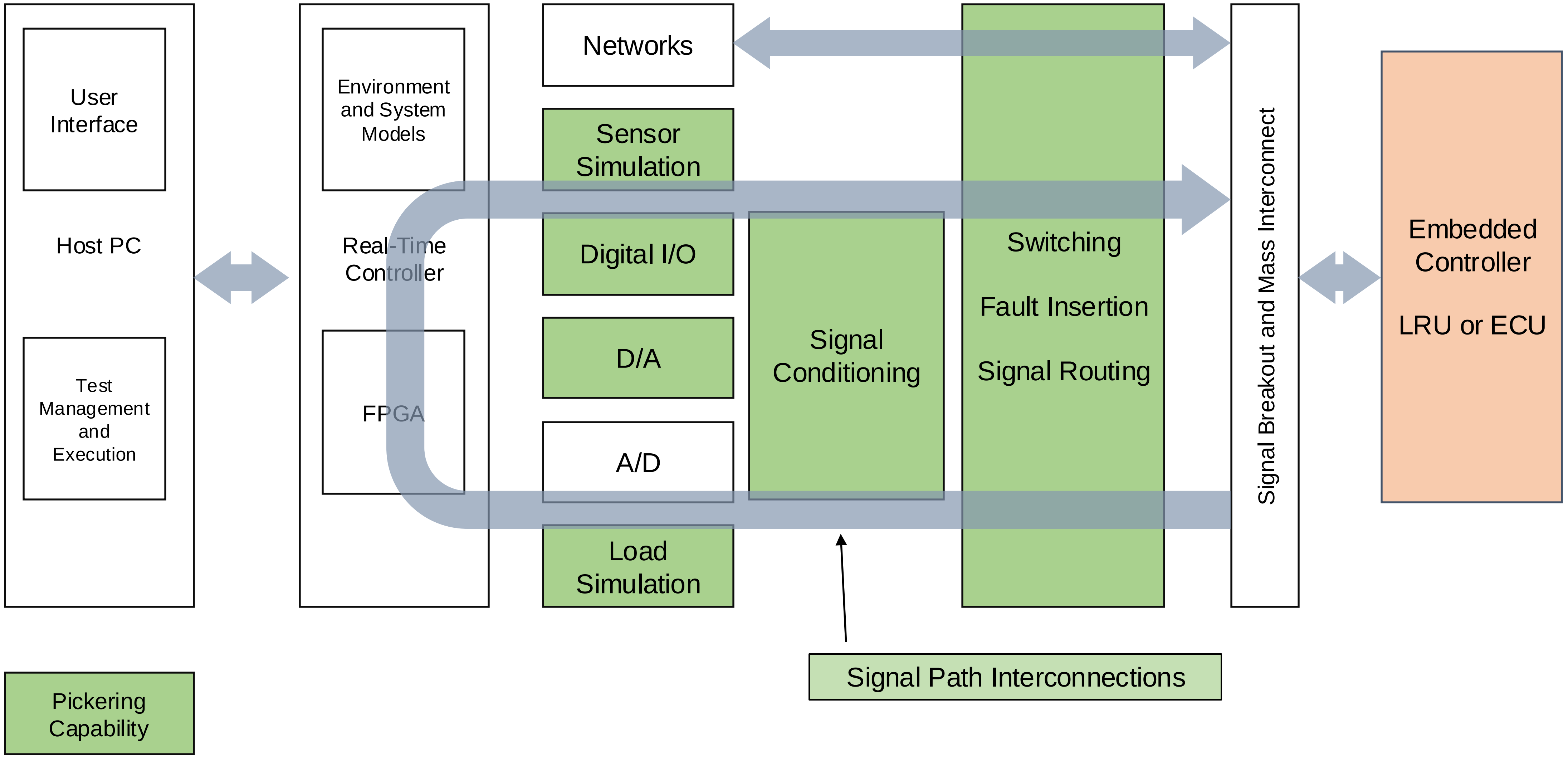
In-house expertise	Some-High
Resources available	Limited-Some
Time-to-Market pressure	Some-High
Budget constraints*	Some concern
Requirements definition	Some changes
Designing for future use	Possible

3rd Party Collaborative System

Extension of engineering team

- **Advantages**
  - Solutions provider and end-user work together to define system architecture.
  - Solutions provider responsible for integration and final checkout of system.
  - End-user has access to system infrastructure.
- **Disadvantages**
  - Up-front effort to fully define system requirements.
- **How Pickering is involved:**
  - Very wide range of high-performance COTS switching, simulation, and cabling.
  - Industry-standard platforms (PXI/LXI) simplify H/W and S/W integration.

Pickering’s Core Competency within a HILS



DMC/Pickering Collaboration

How we collaborate

- Present end-user with a single point-of-contact for the integrated HILS.
- Consult directly on planned uses of Pickering products.
- Get feedback or find alternate/better ways to structure things.
- Leverage use of open-platforms to maximize use of core competencies from multiple vendors.
- Provides Pickering with end-user feedback that helps drive product roadmap.

DMC and Pickering

- Battery Management Systems
- Aero/Defense Projects
- Battery/Electrification Projects

Specific Products

- Battery Simulators
- Variable Resistors
- High-Voltage Relays

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DMC/Pickering Collaboration

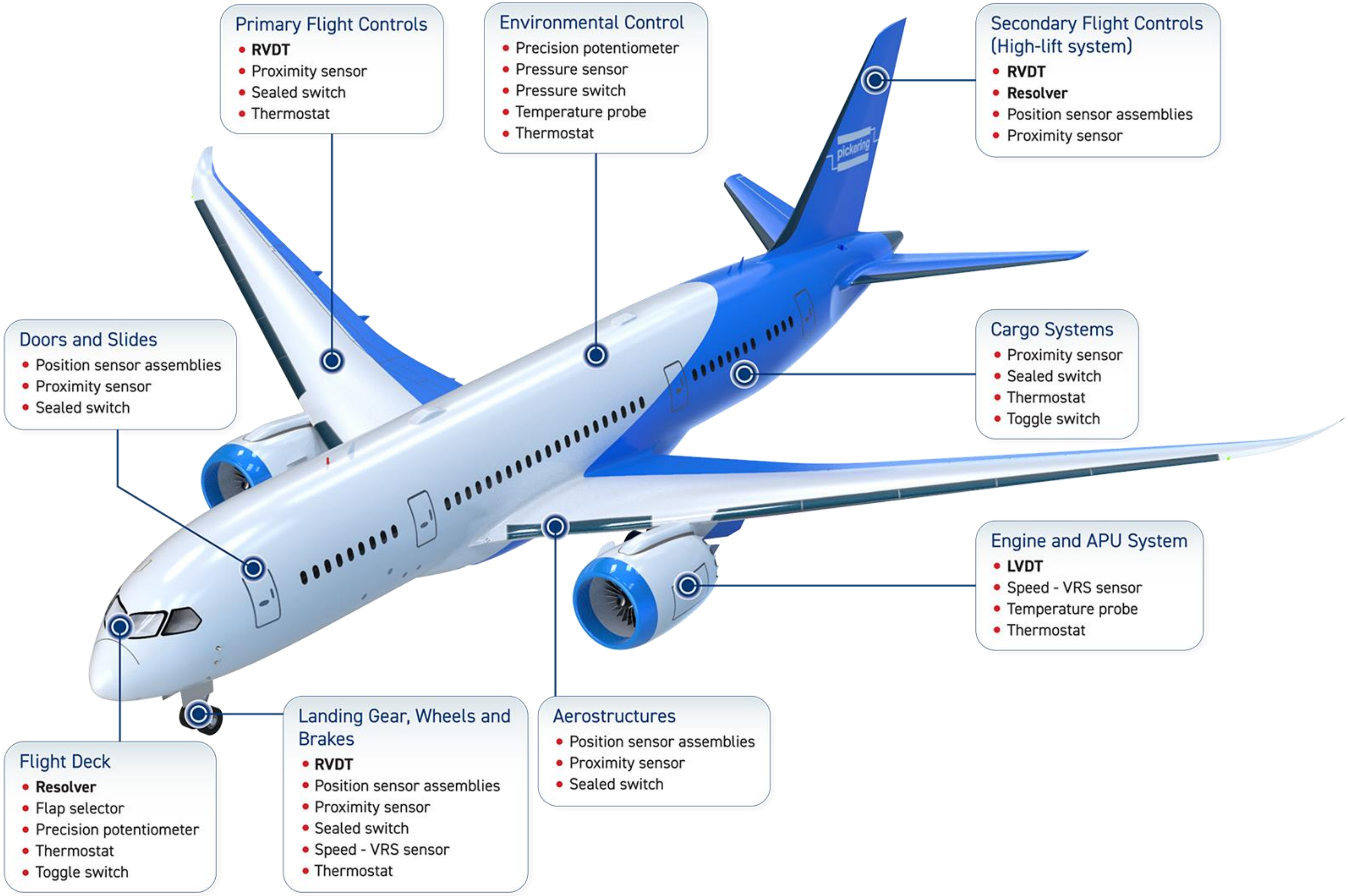
BMS Technology Development

- **Development Process**
  - Listen to our customers' needs
  - Proposal (typical hardware solution)
  - Ask more questions
  - If atypical required, consult with Pickering
- **BMS for 400V traction battery pack**
  - Needed 96x Battery Cell Simulators
  - BMS wouldn’t work with typical resistors or power supplies
  - Enter PI single-channel PXI battery cell simulator (can we get 8 of these on one card?)
  - PI, asked the questions to understand the whys and why nots and think about engineering tradeoffs
  - Had a firm commitment from PI to develop a specific solution which became a COTS product

Case Study

DMC/Pickering Collaboration on Power HIL Test Stand for an Autonomous Air Vehicle

Aerospace HIL Systems Are Challenging



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Aerospace HIL Challenges

- **Longer Life Cycles**:
  - Technology Insertion Programs over 20-30+ years drive evolving regression testing.
  - Comprehensive obsolescence mitigation plan is required.
- **Complexity**:
  - 1000s of signals, more complex LRUs, faster, and higher accuracy simulation.
- **Redundancy**:
  - How to test a system that automatically compensates for faults?
- **Unique Requirements for Aircraft**:
  - Additional simulation required, e.g. LVDT/RVDT/Resolver, altimeter, strain gauge, communication busses, etc.
  - Take-off, landing, terrain mapping, weather mapping, intelligent flight avoidance, long range radar, ground-station communications.

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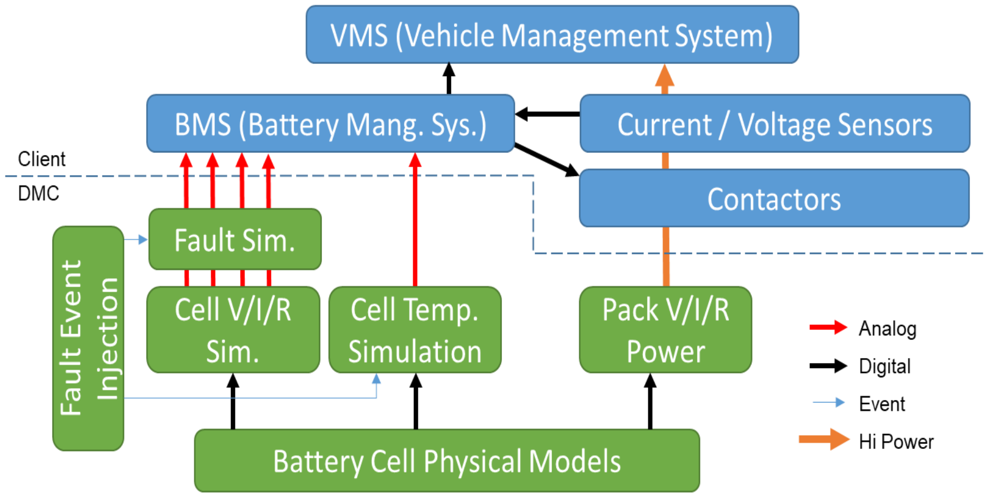
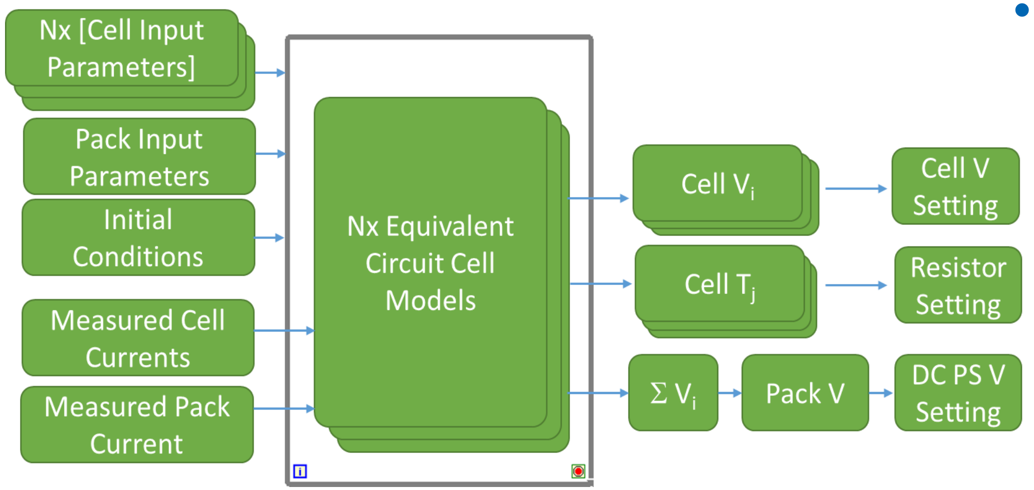
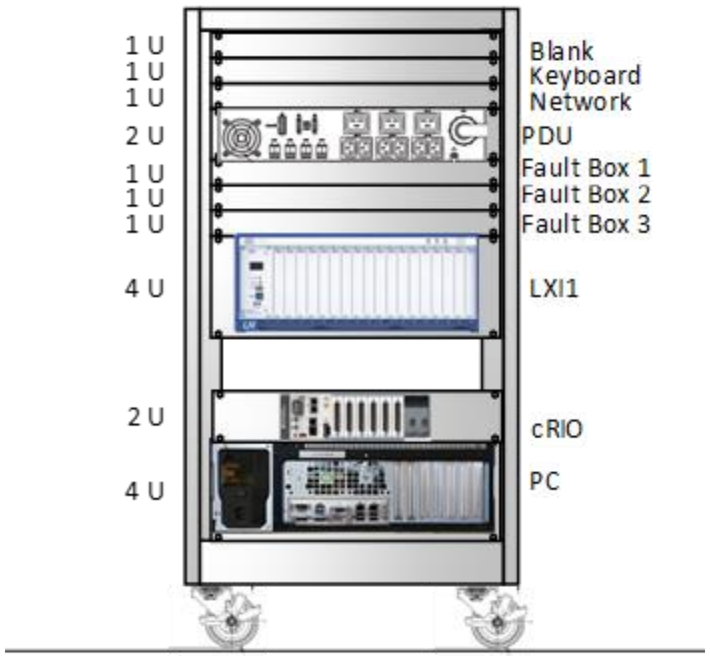
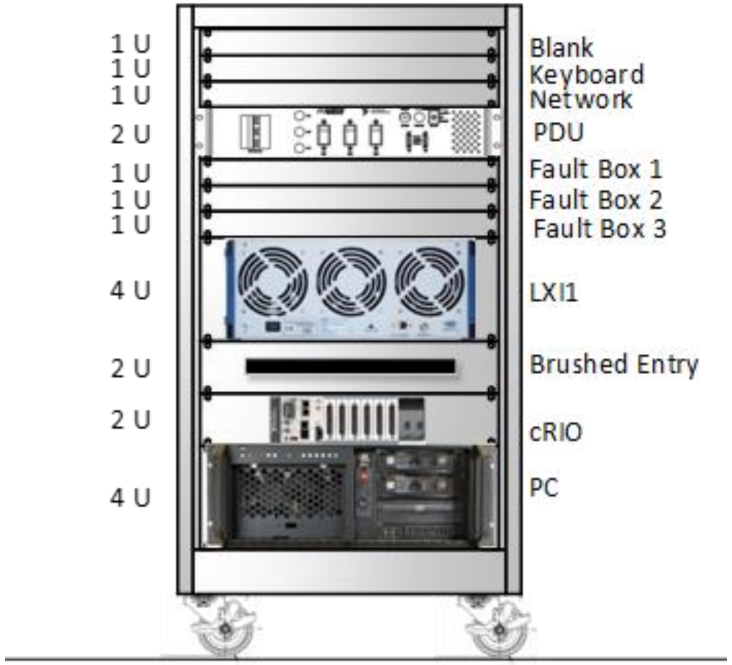
AAV Project Requirements





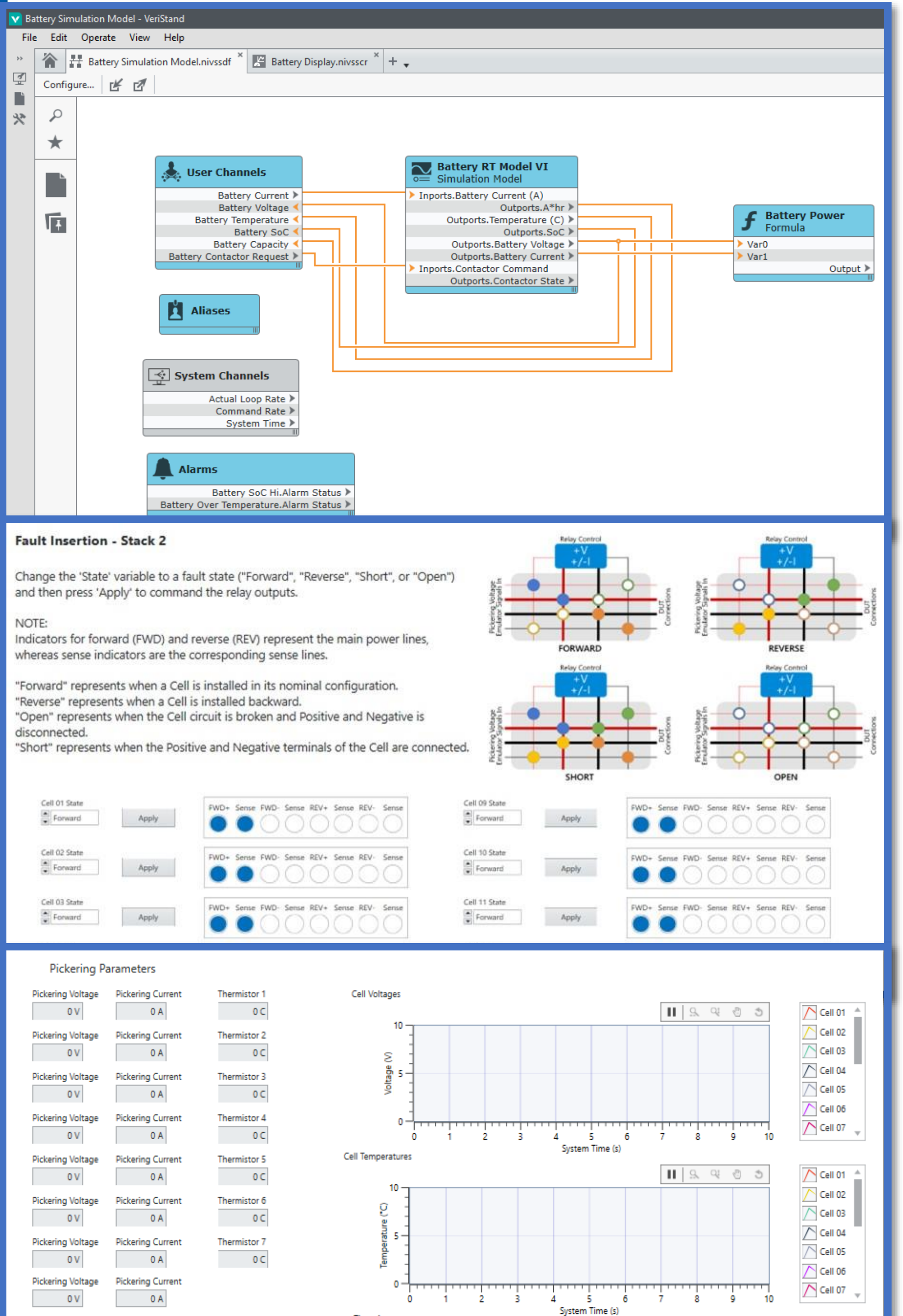
- Rigorous testing protocols required end-user to emulate the function of their AAV battery-pack design.
- Fully test and validate both the Battery Management System (BMS) and flight electronics across a range of normal operating and fault conditions.
- Conventional testing methods could not address safety issues inherent in testing real-life scenarios:
  - Under/over temperature/charge
  - Fault conditions that could occur during the battery pack assembly and/or vehicle operation.





Recipe for Success

- Deep knowledge of what the client was trying to accomplish through multiple discussions.
- Understanding of unique blend of production, HIL, and fault injection testing they desired.
- Deliver hardware and software concepts and started tradeoff analysis within a week of project award.
- Maximize use of COTS hardware and open-platform architecture.
- Maintain costs by using Pickering cell simulator modules in an LXI/PXI chassis, and NI VeriStand & real-time controller.



Why was VeriStand chosen as the software platform?

- Very low startup-cost HIL software system from NI that works well with Pickering and other suppliers' PXI hardware.
- Able to leverage years of experience with VeriStand and integration of hardware within the environment.
- Can be customized to end-user requirements including the battery cell model required for this project.
- Low total cost of ownership.

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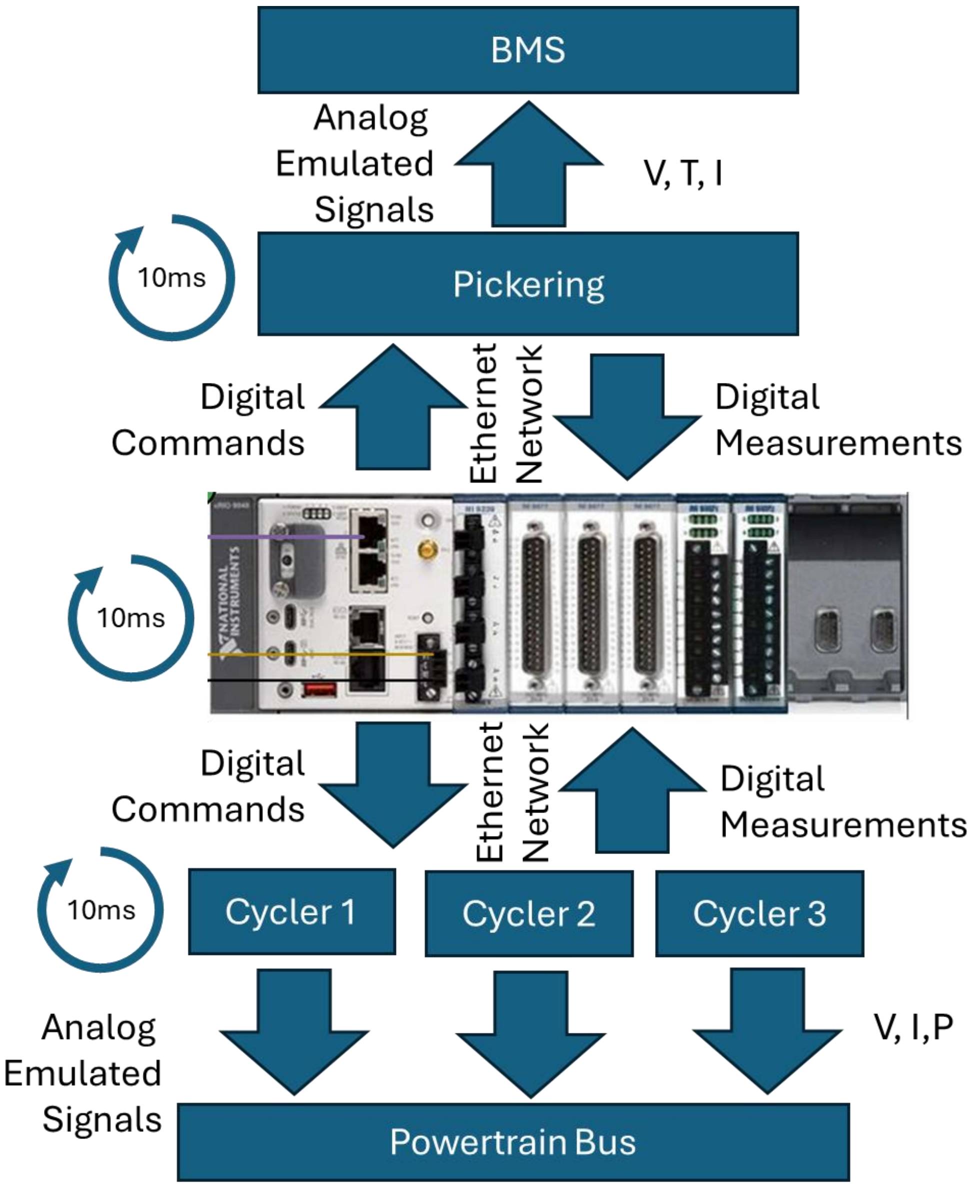
Handling the Unexpected



- The client’s larger test setup-–which we needed to become part of—was delayed and constantly overbooked.
- Parallel vs. Effectively Parallel

Benefits/Results

- **Achieved HIL testing under all conditions:**
  - Fully emulate battery pack that would be difficult to achieve using a real battery
  - Simple RC based battery modelling of V,I T.
- **Synchronized a simulated battery stack with DC power sources:**
  - Three battery stacks and three battery cyclers add complexity not resident with a single-stack
  - Stacks are effectively (but not always) in parallel.
  - System can simulate failures in one or more stacks to measure and 'tune' the reaction of the whole system.
- **Gaining maximum flexibility in sequencing and control:**
  - By using Pickering's VeriStand custom integration, the client owns the code
  - Can take over ownership to sequence their battery emulation and fault injection with their larger flight dyno system.

Lessons Learned and Avoiding Pitfalls

1. **Look toward lowest total cost of ownership**: Taking a collaborative approach resulted in an open-platform that could be expandable without any significant licensing fees.
2. **Maximize use of industry standards**: Using open-standards and open software tools opened the door to a multi-vendor solution.
3. **Use COTS when available**: FPGAs are versatile, however...
4. **Design to scale**: Unable to adapt HIL tester as requirements mature or tests become more distributed.
5. **Leverage solution providers who act as a partner**: HIL is inherently custom, and putting pieces together can be very challenging. Partners need to be able to work in a dynamic environment.

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What's Next: Simulation for NextGen Aircraft

What’s Next: HIL Simulation for NextGen Aircraft

- **eVTOL**: Higher energy density for better power-to-weight ratio
- **AAV**
- **Integrated Modular Avionics** (IMA)
  - Increased Complexity: Need to simulate everything together (Ironbird)
  - Regression testing is more critical as modularity increases
- **Higher Power Requirements**
- **Higher speed real-time simulation**
- **Higher accuracy simulation**
- **Safety & Compliance**: There is more chance of errors with increased complexity

About DMC

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Smart People. Expert Solutions.®

Service Areas:

- Test & Measurement Automation
- Manufacturing Automation and Intelligence
- Enbedded Development and Programming
- Application Development
- Digital Workplace Solutions

Industries:

- Aerospace, Defense & Government
- Automotive and Commercial Vehicle
- Electrification & Energy
- Semiconductor
- Medical & Pharmaceutical

Software Support: VeriStand, LabView Realtime, Mathworks, Simulink, Linux Realtime, QNX & RTX

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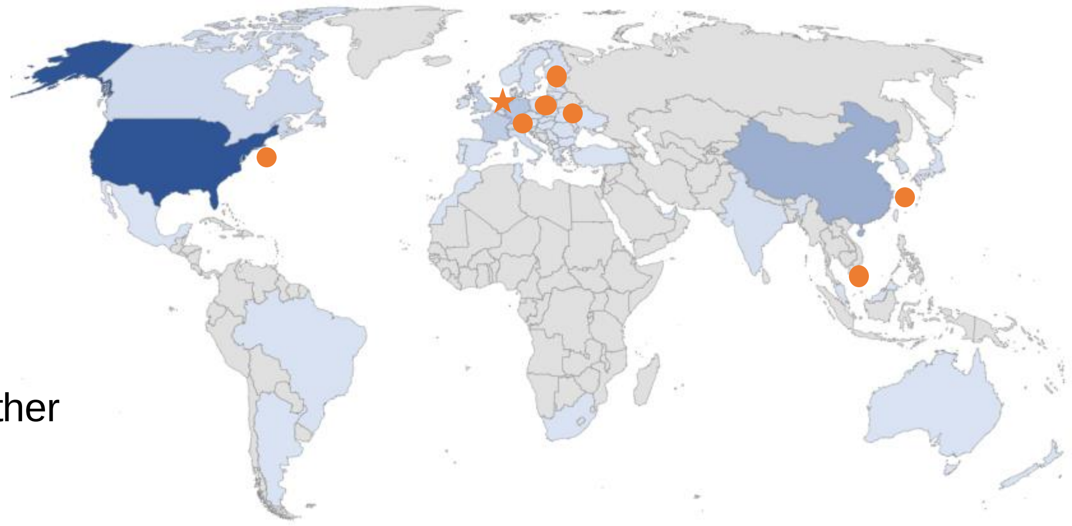
About Pickering Group

- Founded in 1968
- Vertically integrated from relays to subsystems
- Worldwide sales into more than 50 countries
- 550 employees across eight sites
- Headquartered in England
- Sponsor Members of PXISA and LXI Consortium: Industry-standard platforms & interoperability with other vendor hardware
- Long-Term Service & Support



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

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Pickering Interfaces HIL Products

- Switching
  - Low level to 1 kV
  - Up to 40 Amps
- Fault Insertion
  - Up to 40 Amp switching
  - Communication Buses
- Sensor Simulation
  - Thermocouple
  - RTD
  - LVDT/RVDT/Resolver
  - Strain gauge
  - 4-20 mA
- Digital I/O
- Analog Sources
  - Isolated DAC (to 40 V)
  - Battery Cell simulation
- Load Simulation
- Cabling

Q&A

Brent Hoerman

Senior Manager, DMC Inc.

brent.hoerman@dmcinfo.com

Tom Sarfi

Business Dev. Manager, Pickering Interfaces

tom.sarfi@pickeringtest.com

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pickering 25 YEARS IN PXI