Benefits of Model-Based Control and Real-Sim Switching in Electromechanical Test Rigs

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Todd VanGilder, VP of Sales WTI
Agenda

• Challenges in Testing
• Why bring test earlier in the design cycle
• Necessary capabilities and a platform-based approach to test
• Benefits if successfully implemented: case study
Diverging Challenges

The quality challenge is growing, but timelines and budgets are not increasing proportionally.

Engineers must continue to innovate and harness the latest technologies to remain competitive.
Challenges in Every Test Department

The product quality demanded by leadership, customers, and end users comes through sophisticated, customized test systems.

- Accurate Simulation
- Accurate Testing
- Accurate Data
- Accurate Decisions
The Continuum of Testing

Pure Software Testing

Pure Physical Testing

More expensive but more real

Model in the Loop
Software in the Loop
Hardware in the Loop
Deterministic Test Cell
Test Cell
Field Test
V-Model

Tests Performed
- Model-in-the-Loop Test
- Rapid Control Prototyping
- Software-in-the-Loop Test
- Processor-in-the-Loop Test

Tests Performed
- Field Test
- System Integration Test
  - System Level
  - Vehicle Level
- Physical Test
- Hardware-in-the-Loop Test

- Requirements
- System Design
- Subsystem Design
- Detailed Component Design
- Code Generation
- Build Components
- Build Subsystems
- Integrate Systems
- Build Vehicle First Article

- Feedback
- Test Requirements
Move Test Earlier in the Design Cycle

• Iterate faster
• Reduce cost of test
• Decouple dependencies
• Increase test coverage
  – “Malicious” tests
  – Instantly change conditions

• Requires model-based control capabilities
  – Record and playback of actual operational profiles, noise, so on
  – Simulation of components surrounding the DUT
Systems Engineering Design Methodology

Software Development

Controller Hardware Development

Mechanical Hardware Development

Other Subsystems

Systems Integration Lab
- Functional Test
- Software Test
- Mechanical Test

Software/Controller Validation (HIL)

System Test Rig

Rigs Simulation MIL/SIL Test Management Test Set, System Test, Review

Rigs Circuit Simulation System Simulation Functional Test Functional Test and HIL for Qualification

Rigs Modeling and FEA Characterization Validation

WTP Wineman Technology Incorporated
Cost of Early Capture of Software Defect

<table>
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<tr>
<th>Test Type</th>
<th>Cost Multiplier</th>
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<td>Design Review</td>
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“By using a common validated automated test platform based on National Instruments technology, our design and test engineers can collaborate earlier in the design process and test more extensively, which resulted in an 86 percent reduction in cost per embedded software defect.”

– Senior Director of Quality and Regulatory Affairs

*Based on National Instruments benchmarking of a leading medical company
Capabilities Required to Move Test Earlier

- Model-based control
- Real-time accurate simulations
- Flexible architecture for real/sim switching
Need for Simulation & Modeling

Desire to more closely replicate stimuli and match real-world conditions:
- Record and playback of actual road profiles, noise, etc...
- Model-based control to simulate components surrounding the DUT

By more accurately simulating DUT environment, test organizations can:
- Test earlier in the design cycle (decouple dependence on other system components)
- Decrease the cost of test
- Increase the possible test scenarios
- Increase test efficiency (test automation, no pitstops, driver changes, etc...)
Test Workflow

1. Put the DUT in the right state.
   - Command DUT
   - Change environment

2. Measurements
   - Sensors
   - Comms Buses

3. Manage Data
   - Storage
   - Analysis
   - Reporting

4. Manage Test systems.
   - Maintenance
   - Monitoring
   - Obsolescence

Results

DATA!
Multiple Approaches To Test Systems

CLOSED SYSTEM

“Vendor Knows Best”
Fixed Functionality
Closed Ecosystem
Customer Pays

PLATFORM-BASED SYSTEM

“Customer Knows Best”
Customizable Solution
Open, Vibrant Ecosystem
Customer Designs

FULLY CUSTOM SYSTEM

“Customer Does Everything”
Ground-Up System
No Ecosystem
Customer Maintains
One Platform Approach

NI SERVICES AND SUPPORT

THIRD-PARTY SOFTWARE

WEB SERVICES
PYTHON
C
The MathWorks, Inc. MATLAB®
.NET
VHDL
AND MORE

NI PRODUCTIVE DEVELOPMENT SOFTWARE

NI MODULAR HARDWARE

THIRD-PARTY HARDWARE

ARDUINO
ETHERNET
USB
GPIB
SERIAL
LXI/VXI
AND MORE

MATLAB® is a registered trademark of The MathWorks, Inc.
One Platform Approach

NI SERVICES AND SUPPORT

- 700+ Field Engineers
- 700+ Support Engineers
- 50+ Worldwide Offices

Open Connectivity
- 10,000+ Instrument and Device Drivers
- 1,000+ Sensor and Motor Drivers

Add-Ons
- 400+ Software Add-Ons
- 5M+ Tools Network Downloads

Support

Community
- 300,000+ Online Members
- 450+ User Groups
- 9,000+ Code Examples

Academia
- 8,000+ Classrooms Worldwide

Partners
- 1,000+ Alliance Partners
- Industry-Leading Technology Partners

NI MODULAR HARDWARE

NI PRODUCTIVE DEVELOPMENT SOFTWARE

THIRD-PARTY SOFTWARE

THIRD-PARTY HARDWARE
Hardware-in-the-Loop

Connectors
- Bulkhead connectors that are compatible with the DUT

SLSC (Switches, Loads, Signal Conditioning)
- Fault insertion
- Loads to simulate real world conditions
- Front end signal conditioning

Software
- User Interface
- Stimulus Profiles
- Control
- Data logging

DAQ and Processing
- I/O
- Real-time models
HIL Bench Architecture

ECM ➔ FPGA ➔ RT ➔ HOST

On-Times ➔ Engine Model ➔ Speed
NI VeriStand
Real-Time Testing and Simulation Software

- Stimulus generation
- Data logging
- Single-point I/O
- Alarming
- Calculated channels
- Run-time editable user interface
- User management
- Multi-chassis synchronization
- Closed-loop control
- Deterministic model execution
NI VeriStand System Architecture

Windows (Host)
- Test Script
- UI
- Host Utilities
- Analysis

VeriStand Gateway (.NET API)

Ethernet

LabVIEW RT (PXI or cRIO)
- Models
- RT Sequences
- CSV Player
- RT Utilities

Channel Data (Engineering Units)

VeriStand RT Engine
- CAN
- FPGA
- Analog IO
- Digital IO

CCP/XCP
- Vehicle Buses
- Custom Signals
- Analogs
- Digital S

Internal Memory

ECM
## HIL Architecture Built on the NI Platform

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<th>Digital</th>
<th>RF</th>
<th>Camera Frames</th>
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<td>MAC Panel</td>
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<td>ECU</td>
<td>LRU</td>
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<tr>
<td>Physical Device</td>
<td>ECU Connectivity &amp; Loading</td>
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Challenges of Modern HIL Test

- Increasing Complexity
- Changing Requirements
- Lack of Manpower
- Unrealistic Schedules
HIL Example Signal Paths

An example signal path for a HIL test system is shown below.
Connecting to an ECU

HIL Test System

Example Wiring Harness Connector

G12 Mass Interconnect

Example ITA
Full Height HIL Test System

- Main Power Control
- Test panels
- VPC G12 Mass Interconnect
- Custom Loading
- Programmable Power Supplies
Reusable, Unified Test Architecture

Test Requirements

Desktop Algorithm Testing

Unit V&V Test

Integration and System Test

Production Test

A SINGLE TEST PLATFORM

Data and Test Results
Case Study Slat/Flap Controller Rig

The Challenge:

Create a Universal Test controller to cover all aspects of Flap and Slat System test (FSECU). Should be capable of SFECU ATP, SFT, Engineering, Iron Bird core stand, SITS testing, System testing, ISTCR, and Field service.

Must be designed to be modular and work for multiple aircraft platforms.
What Is an FSECU?

**Flap and Slat Electronic Control Unit**
Traditional FSECU Test System

Physical Testing - Single Wing Actuation Test Systems

HIL Testing - ATP Test System

HIL/MIL Testing - Software Test Station
Single Common Test Platform
- Same load tables used in Physical Test, ATP and Iron Bird
- Same SFECU rig used for development, ATP, Iron Bird, SITS, ESIM. (entire design “V”)

Modular Hardware
- No hard wiring or plumbing to connect UUT or Load Tables
- Eliminates traditional harness construction uses interconnect boards

Open Software Architecture
- Reflective Memory architecture allows stand to run in segregated or integrated mode
Test Rig Overview
One test solution that can execute both Physical Tests and Simulations

How Did The System Work?
Software is very Modular and each module communicates with the other modules via Reflective Memory.
Results
In Summary

✓ Bring test earlier in the design cycle

✓ Ensure you have a partner with the necessary capabilities and a platform-based approach to test to help you achieve your desired results
Learn More

• Visit https://www.winemantech.com/services/hardware-in-the-loop-test-systems/ to:
  – Contact us at: sales@Winemantech.com to learn how we can help you implement your next HIL system
Who We Are

We help customers simulate real-world environments and get the data needed to make insightful decisions throughout product development.

- Est. 1991
- NI Gold Alliance Partner
- HQ in Saginaw, MI, 47 employees
  - 3 regional locations
  - 20,000+ ft² in production facilities
- Certified veteran-owned small business
- $12M in sales
What We Do

Specializing in custom equipment to provide insight through electromechanical test.

Hardware-in-the-Loop Systems
Hydraulic Test Systems
Dynamometer Systems
Real-Time Controllers and Data Acquisition
How We Work

Meeting your challenges – from extending bandwidth to creating test solutions for revolutionary products.

- Demanding Timelines
- Specific Requirements
- Test Expertise
- Simulation Expertise
- Technology Expertise
- Internal Bandwidth
- Standardization Projects
Why Customers Choose Wineman

Get the strength of a large test system development team and the flexibility of a partner nimble enough to develop a custom solution.

Partnerships  Industry Knowledge  Data-Driven Approach  Custom Systems
National Instruments Partnership

- Americas Partner of the Year 2018
- Outstanding Technical Resource Award 2015 - 2018
- HIL Specialty Partner
- LabVIEW Tools Network Product of the Year 2014, 2017
- ni.com/Wineman
- ni.com/testcell