ODYNE Hybrid Systems™

All-Day Hybrid Power On the Job

Model Based Design:

Balancing Embedded Controls Development and System Simulation

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Topics

- Odyne
- The Project
- System Model
- Summary

About Odyne Systems LLC

ODYNE Hybrid Systems™

- A clean technology company focused on development and deployment of hybrid systems for trucks over 14,000 pounds
- Intermediate stage manufacturer, can be installed on new vehicles or retrofitted
- Handles multiple chassis / engine configurations
- Handles multiple customers/operators, applications and duty cycles
- Supply agreement / partnership with Allison, JCI and Remy

Allison Transmission. Johnson Controls READY TO POWER YOUR FUTURE REMY ELECTRIC MOTORS™

Target Market / Applications

Aerial Device (Bucket Truck)

- For maintenance and construction of electric lines

Cranes/Digger Derricks

- For installation of electric poles and transformers

Underground Utility Vehicle

- For construction and maintenance of underground natural gas and electrical lines

Hybrid Bucket Truck

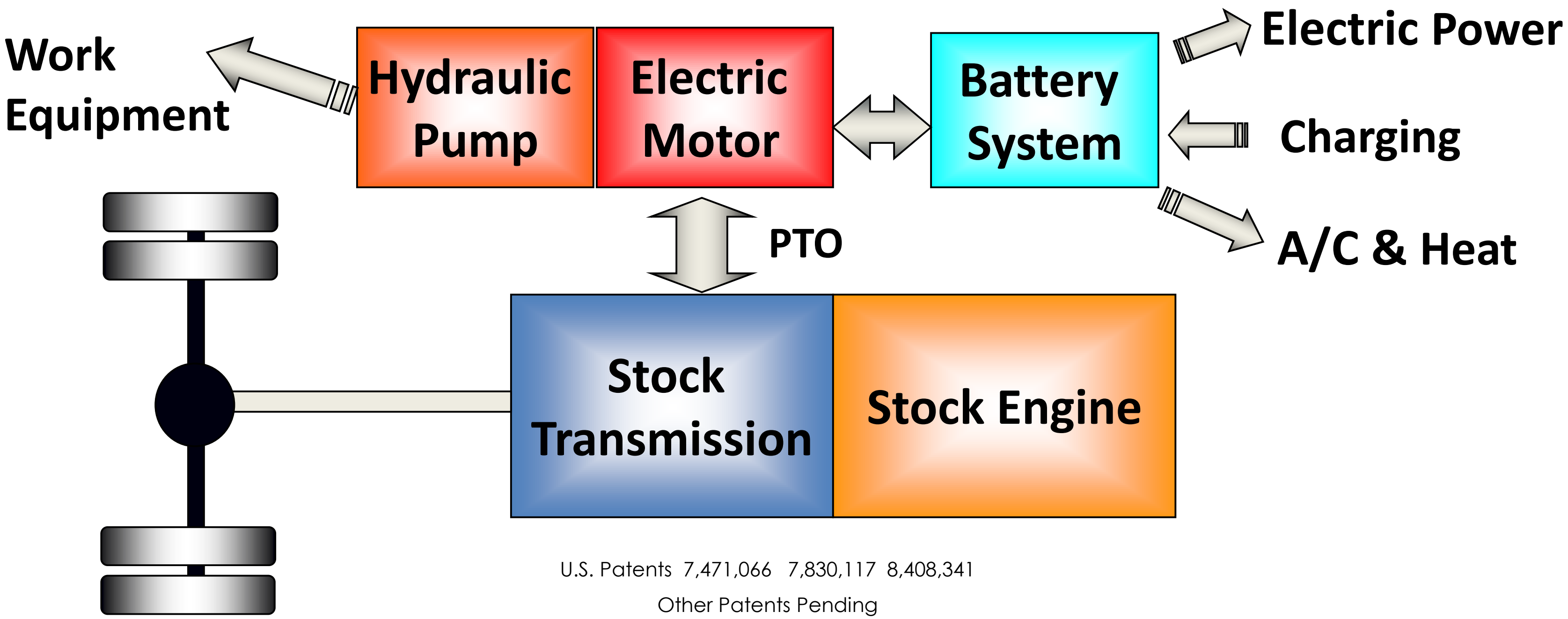
Hybrid Digger Derrick

Hybrid “Pie Wagon” Utility Truck

Hybrid Compressor Truck

Hybrid Crane Truck

System Architecture (PHEV)



U.S. Patents 7,471,066 7,830,117 8,408,341

Other Patents Pending

Parallel Hybrid Solution

- Provides launch assist & regen braking while driving
- Provides all jobsite / stationary work support
- Can recharge battery from IC Engine while maintaining stationary work support
- No modifications required to drivetrain

Project Goals

- Improve system simulation capabilities to help during development to quickly evaluate the performance across all applications
- Combine controls development and simulation development so that they support each other with minimal effort
- Leverage the same control code used during automatic code generation for the embedded code in production

Requirements / Considerations

- Relatively easy to implement & maintain / grow
  - Low cost / resource
  - Ability to adjust the level of fidelity
- Must support current control development tools
  - MATLAB / Simulink / Stateflow
  - MotoHawk
- Use for performance evaluation and control development
  - Software in the loop (SIL), no hardware required
  - Easy to import data, dyno testing or field / telematics

Requirements / Considerations

- Support different components, chassis, engine, etc.
  - Multiple configurations depending on Customer / Application
  - Characterize / parameterize each one separately
- Ability to have everything in one tool and as close to production intent as possible
  - Have control code, chassis dynamics and system dynamics all together
- Main focus is on vehicle level performance based on specific duty cycles but can also be used for component level performance and code development / calibration

Development & Simulation Process

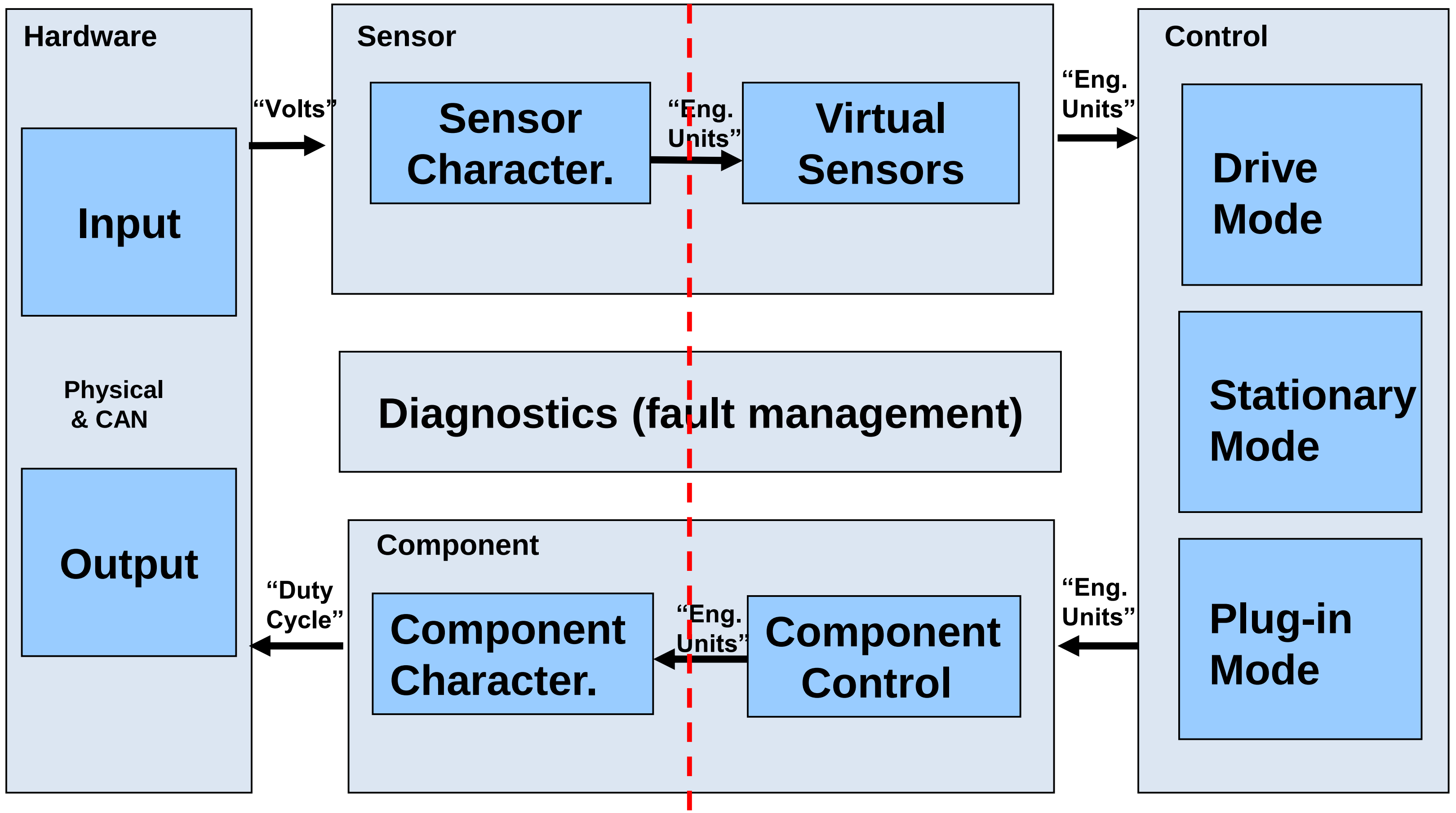
Incorporated into the Verification and Validation process

- Increases our capability to develop and verify things before actually implementing on the vehicle Verification
- Will support changes like new features/functions/components, continuous improvements, production revision/calibration/ release, test cases
- Will handle simulation at various levels (vehicle-system-component); the data and testing will be used to validate the accuracy, analyze potential changes to predict the effect, and to support controls development

Software Architecture Changes

- Need to separate the main Controls from the hardware layers
  - Hardware layer contains the physical I/O (RTOS) and converts to signal in engineering units
  - Controls layer contains all the functionality and is exactly the same as what is used for production
  - Similar to AUTOSAR methodology
- Must clearly define and manage the architecture and interfaces
  - Commonize between Control and Plant model
  - Establish data definitions and attributes

Software Architecture Changes



* Only needed for embedded controls

* Used for embedded controls & simulation

Architecture Management

- Essential to use the Control and Plant models to develop robust embedded control systems
  - Control algorithm development, simulation, data analysis, and implementation are all tied together
  - The coordination of interfaces / definition reduces issues
  - Can be used in all phases of development
- Allows for the collaboration across tools and resources
  - Control and Plant model development
  - Commonizes testing and data collection efforts
    - Can use data from all vehicle and component testing
    - Can use data from telematics of actual customer usage

System Model Overview

- System Model = Control (HCU) + Plant (Vehicle & System)
- Capable of simulating the Drive mode to evaluate Fuel Economy (conventional vs hybrid)
  - Used generic models provided with SimScape and added additional details
  - Utilized Allison specifications to improve transmission model
  - Utilized JCI specifications to improve Pack (BMS) model
- Incorporated HCU code used on production vehicle
- Some components handled individually and some combined together

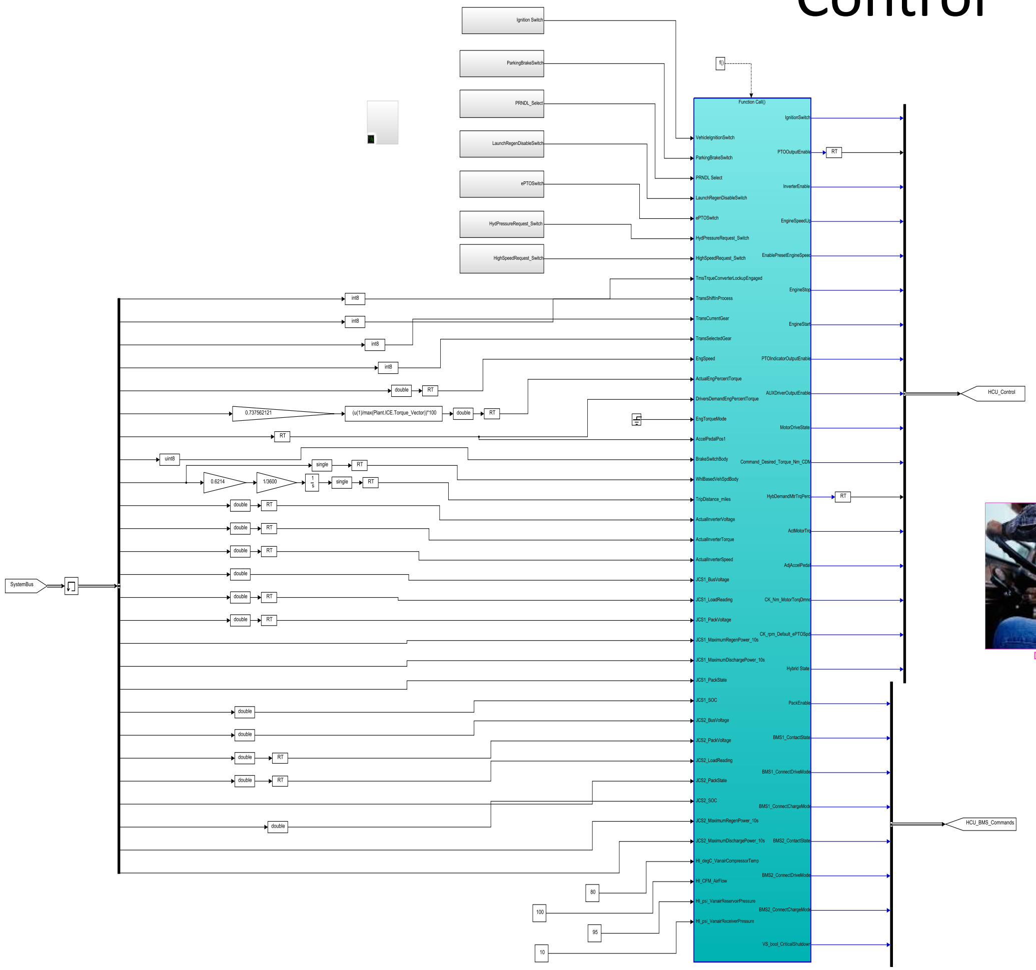
System Model Overview

Simscape™ is being used for System modeling

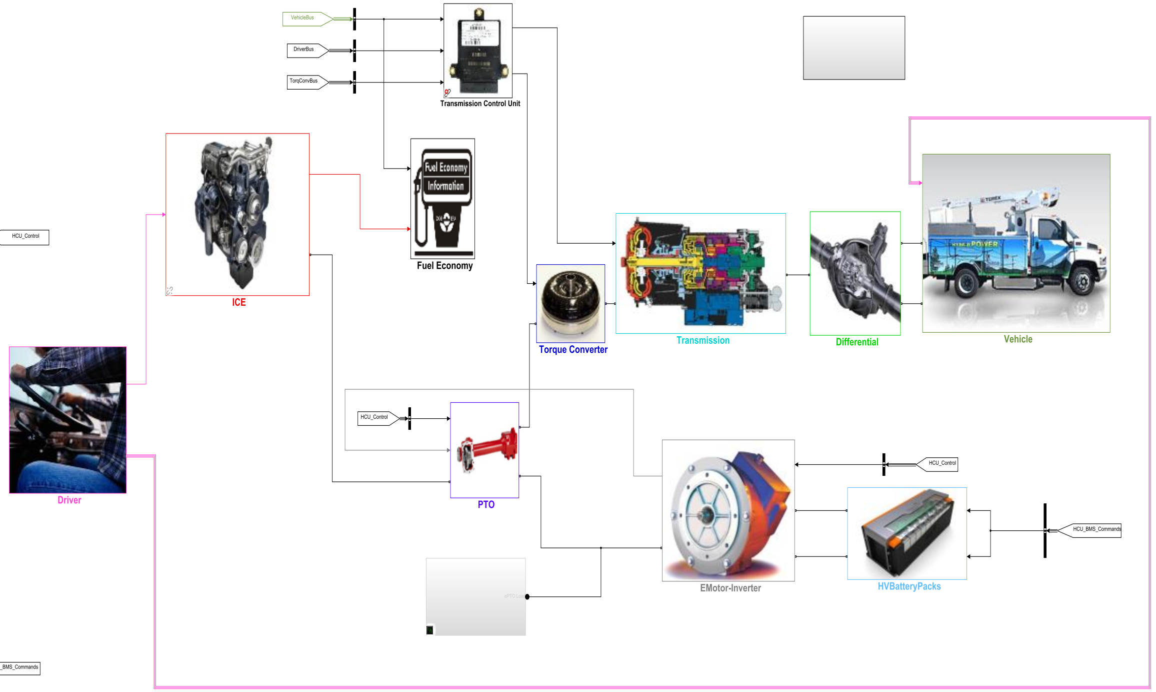
- Simscape™ is a multidomain physical system modeling environment from MathWorks
- Simscape™ also includes the ability to create custom blocks using the object-oriented Simscape or Simulink modeling language
- We are utilizing Mechanical, Electrical, Driveline and Power Systems domains
- Allows for Seamless integration of HCU code which was developed in Simulink/Stateflow

System Model Overview

Control

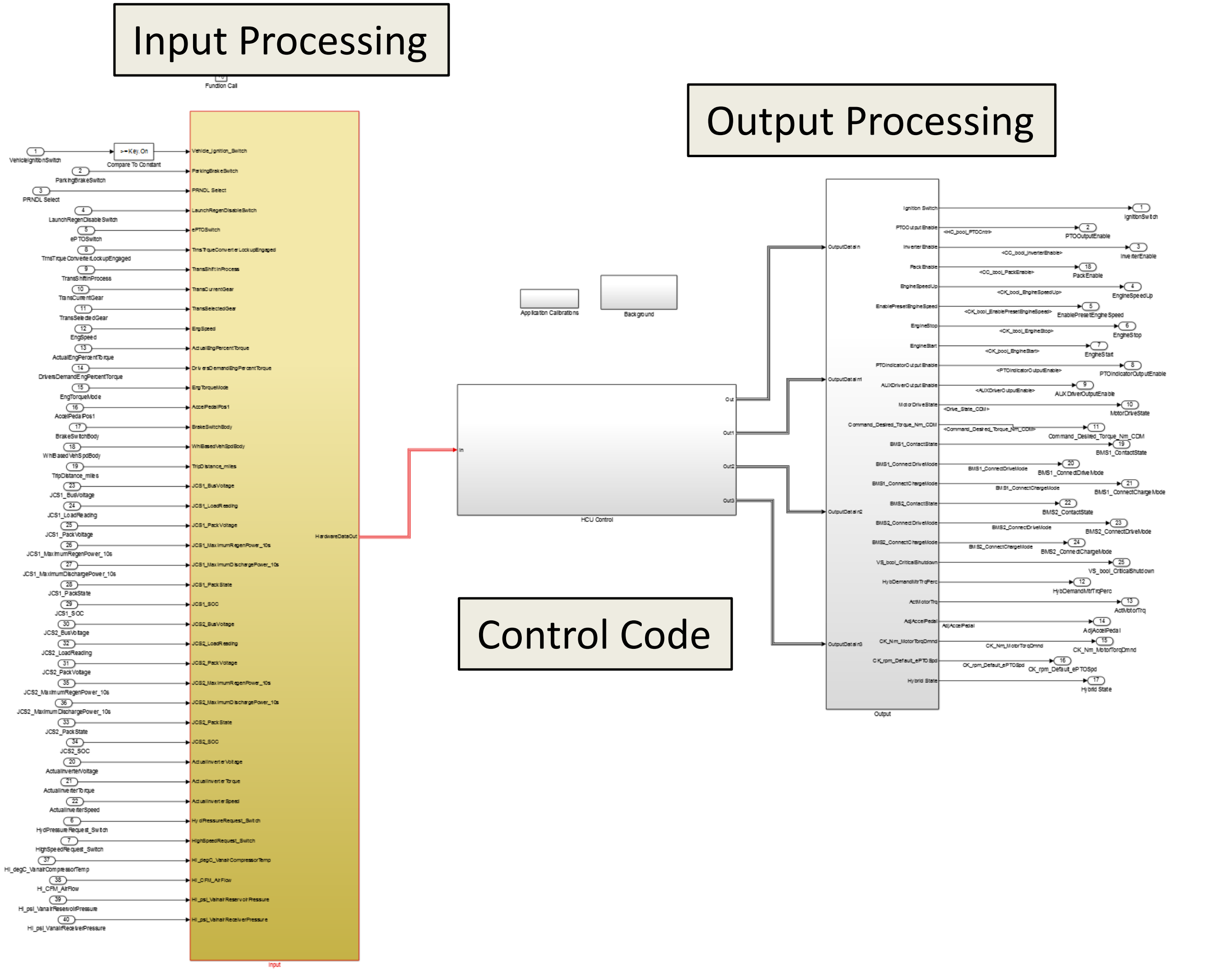


Plant



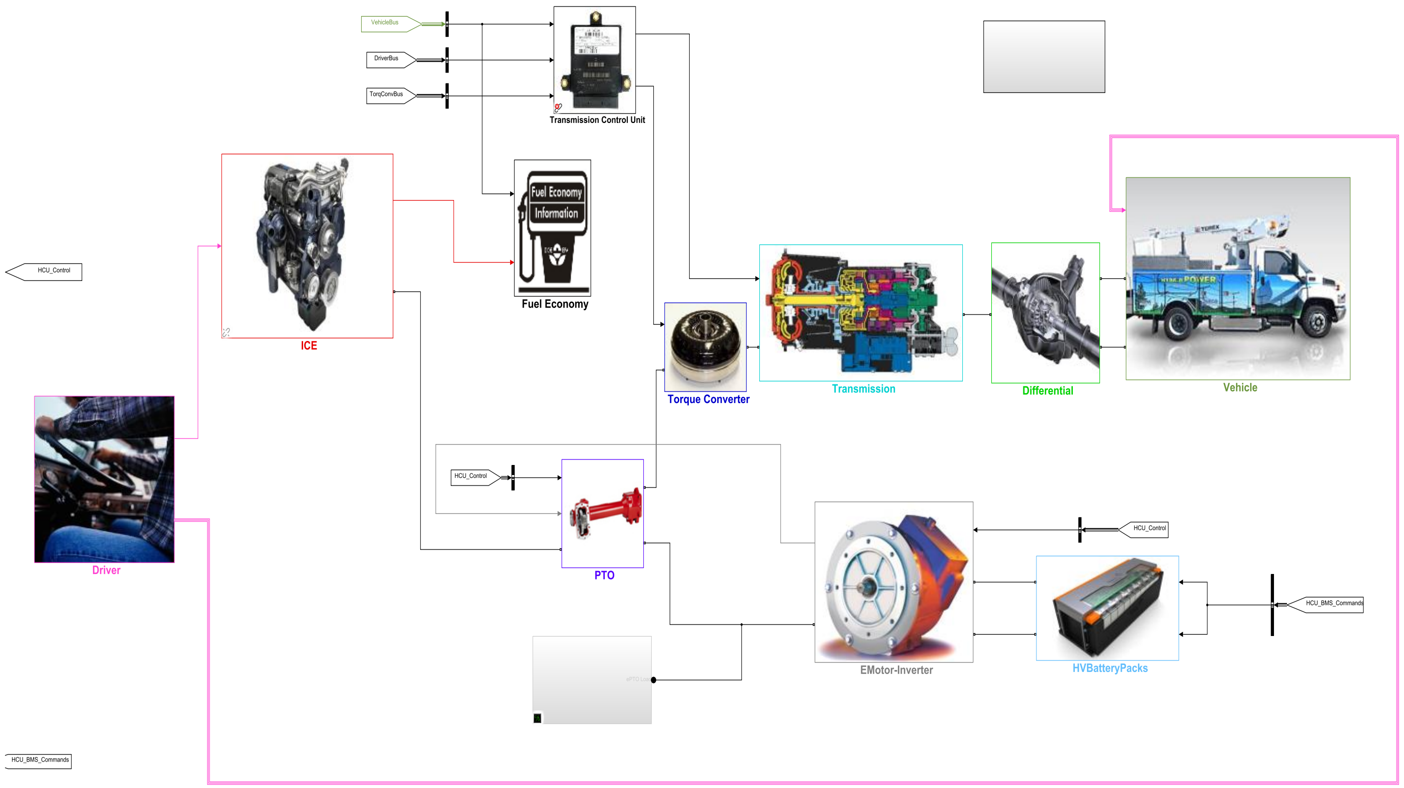
Control Model

- This is the exact same code used in HCU
- Handled with common library block
- This is why the architecture management is very important
- Some input and output processing is required

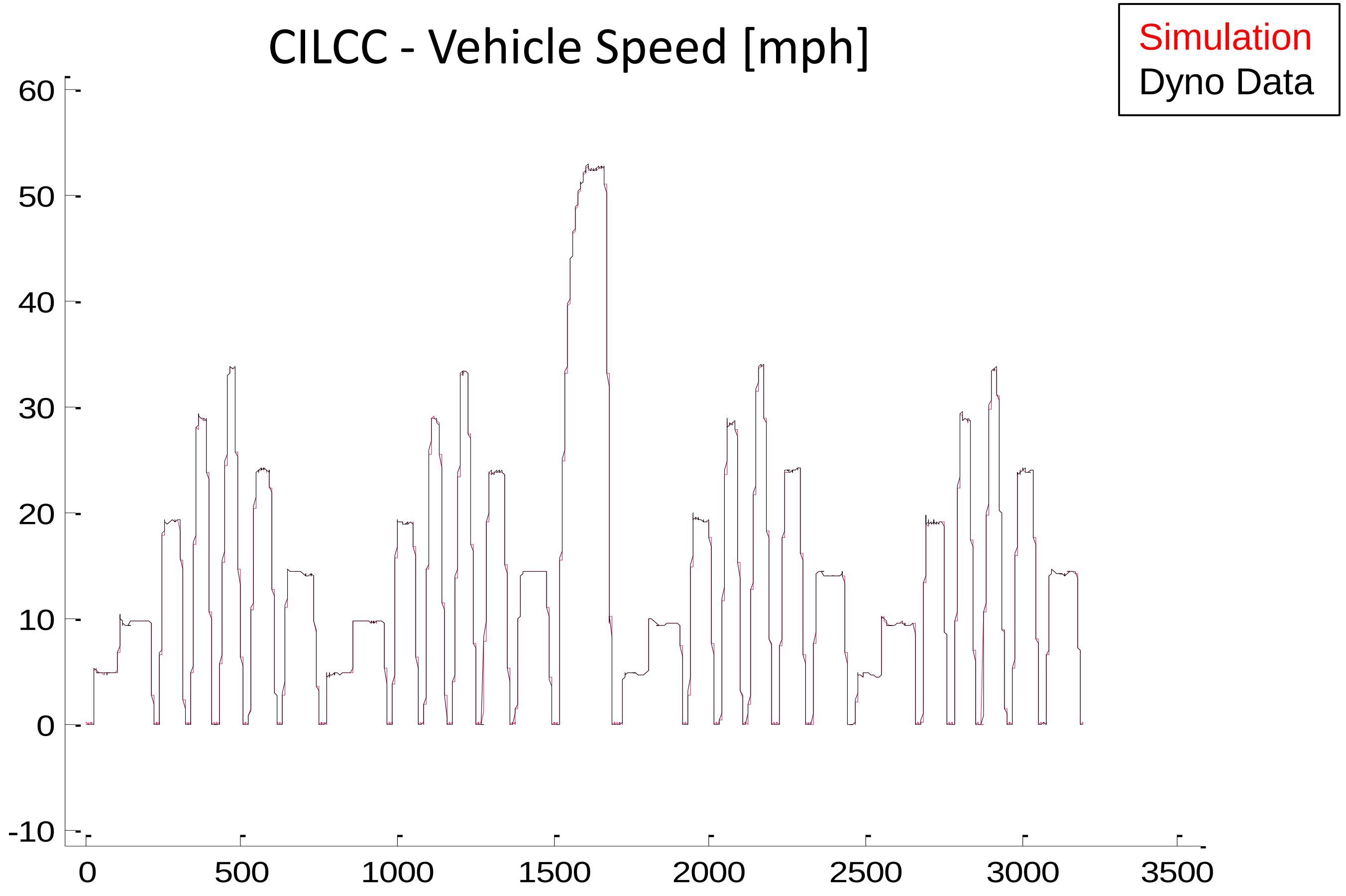


Plant Model

- Handles multiple chassis configurations
  - International Chassis & MaxxForce Engine
  - Ford Chassis & Cummins Engine
- Handles multiple drive cycle profiles
  - CILCC, Orange County, custom (telematics field data)
- Used chassis dyno test data to correlate/characterize simulation

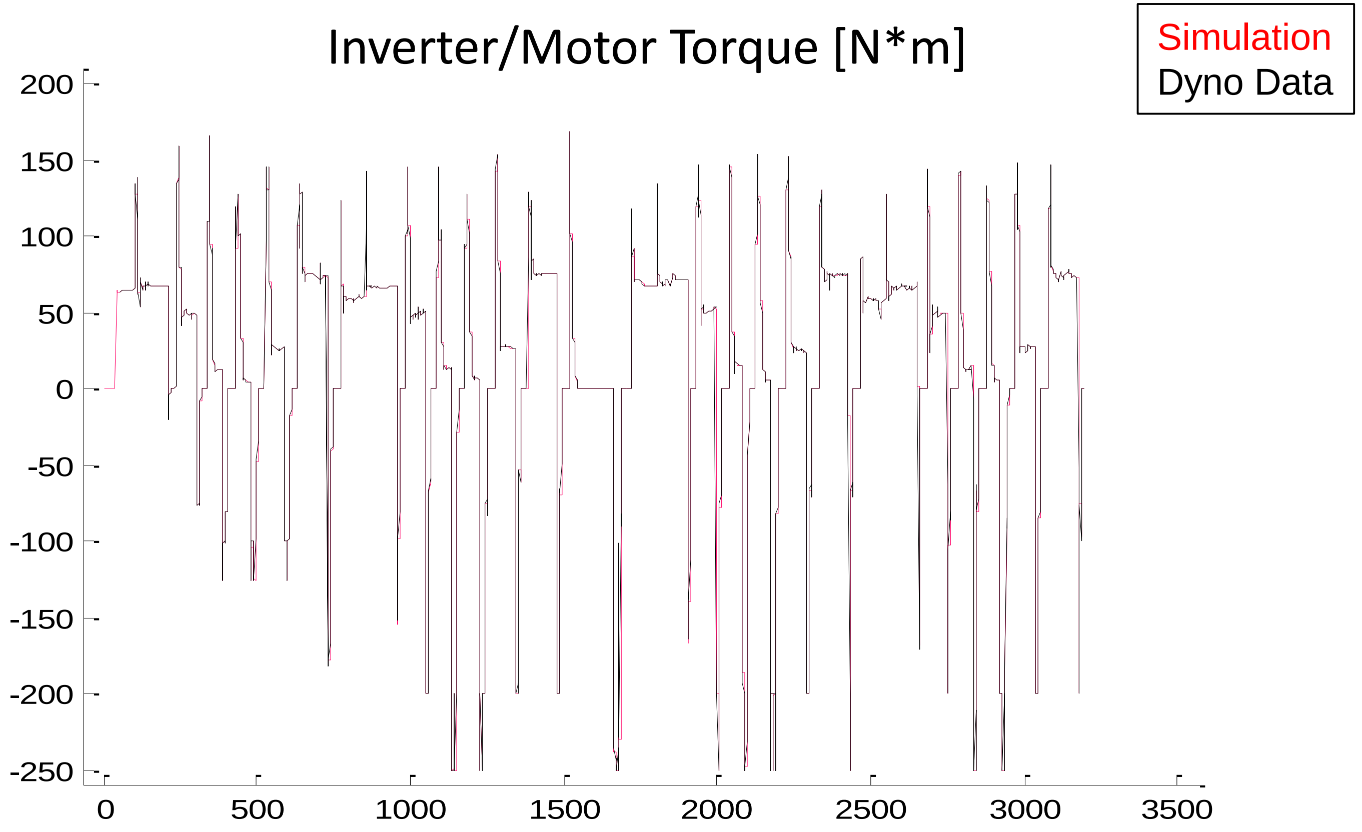


Model Characterization / Verification



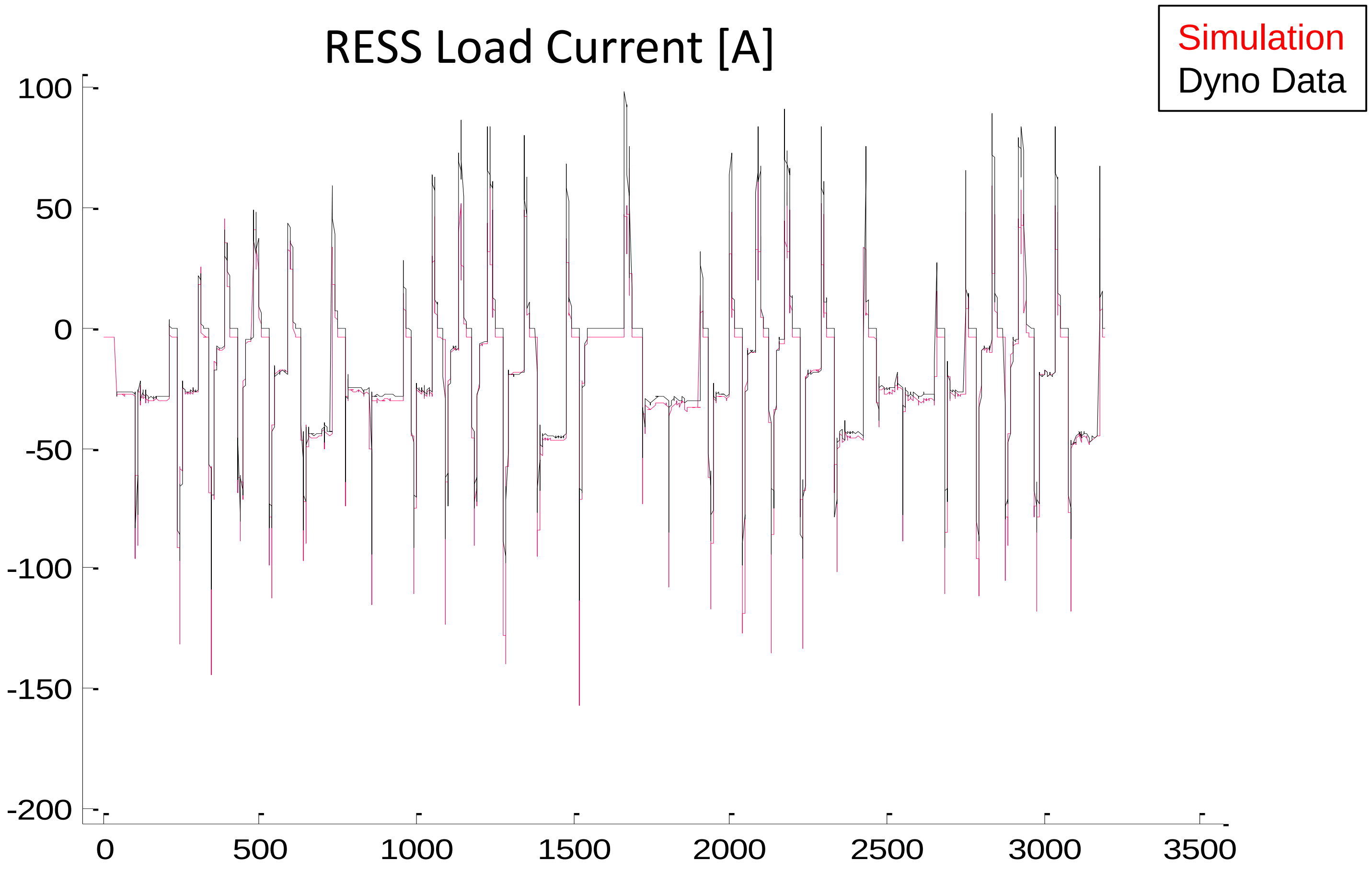
- Very close, except for small transients

Model Characterization / Verification



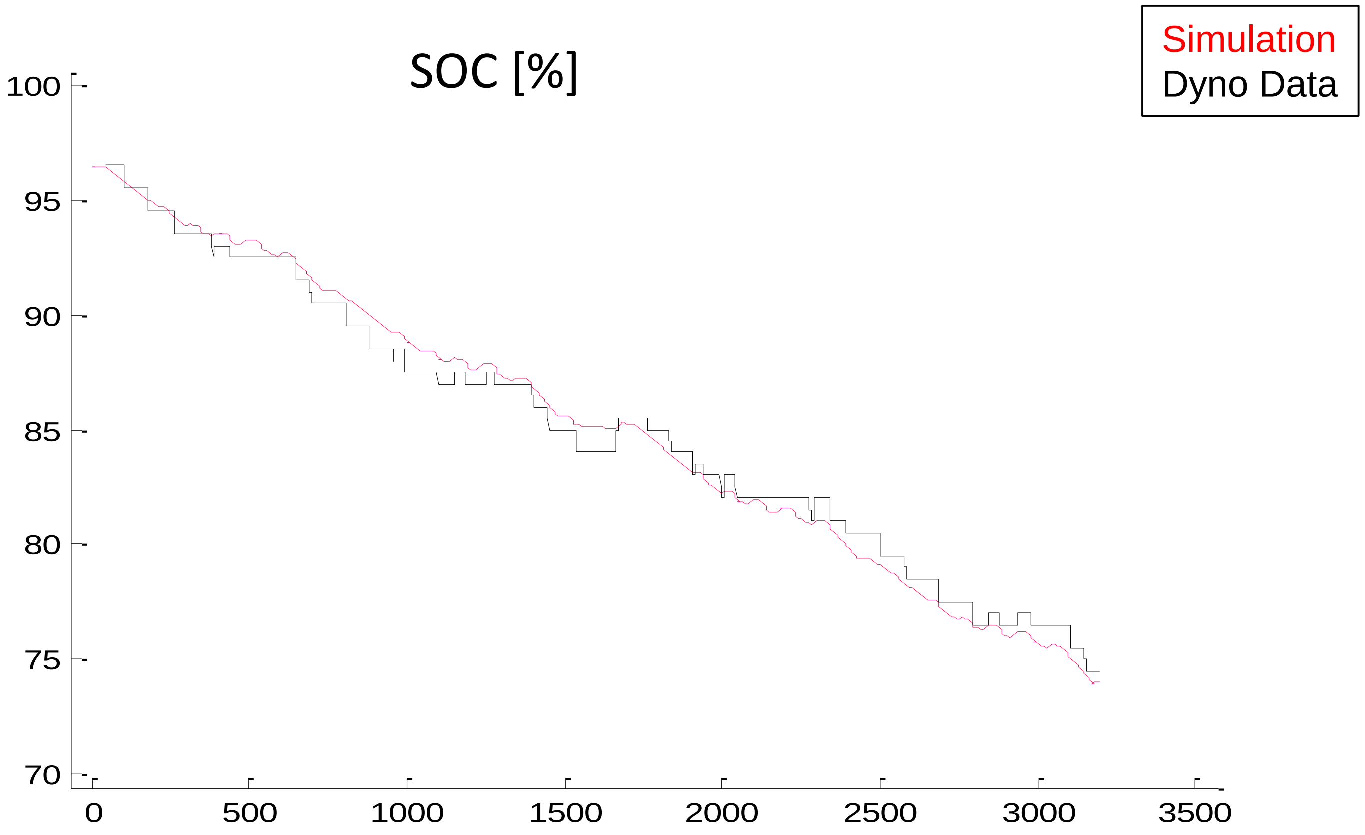
- Some minor differences in launch / regen transitions

Model Characterization / Verification



- Small offset, doesn't account for all loads like DC/DC

Model Characterization / Verification



- Follows the same trend

Performance Verification

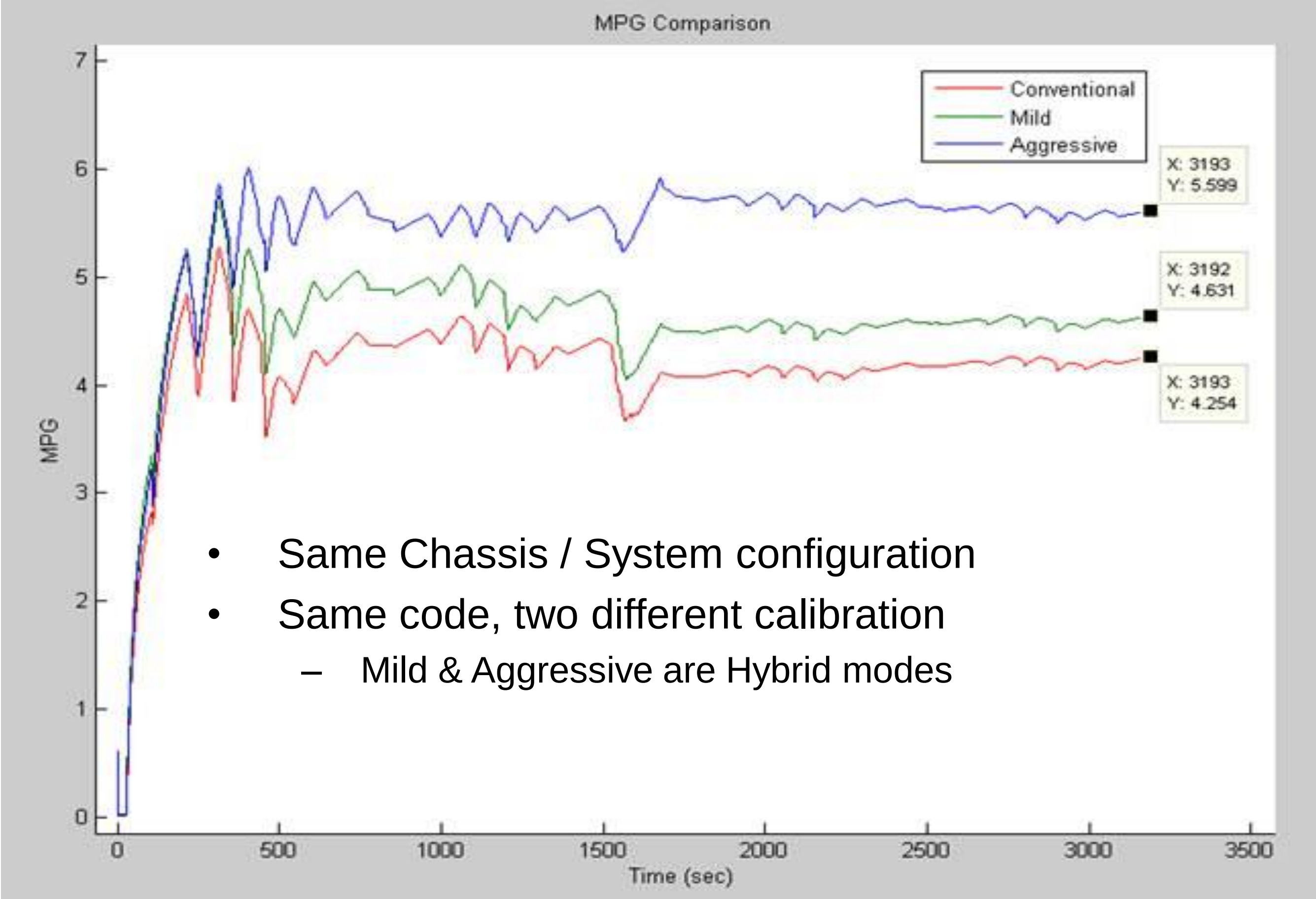
- Typically in model based design the core control algorithms are designed in the “virtual” domain without the embedded hardware or physical constraints/impacts
  - The issue is there are many things in between that will affect the real performance in the field versus the theoretical virtual world
- This approach takes into account all the aspects of automatic code generation
  - Simulation results are verified against actual dyno data
  - Shows good correlation with final production code
- Takes into account fault handling and affects on performance
  - Discovered an issue with MotoHawk OBD block in simulation mode

Performance Verification

- Final simulation performance can be compared to real results (dyno or field)

- Can change control code or calibration to analyze impacts

- Can change vehicle or system to analyze impacts



Next Steps

- GUI to make setup & simulation easier
- Automatic Report Generation
- Utilize MatLab system optimization tools
- Adding new capabilities for ePTO, Plug-in charging and Emission
- Adding new components
  - DC/DC, On-board Charger, Electric A/C, Heat, Exportable Power
- Evaluating full work day performance
  - Driving and jobsite

Summary

- Now we can balance and tie together all aspects of embedded controls development, calibration, testing, data and simulation
- Now we can use the System model to simulate performance and evaluate characteristics quicker than on real hardware
- Provides the appropriate level of development and simulation to allow Odyne to optimize the system
  - Ability to customize based on customer usage
  - Ability to customize based on application

ODYNE Hybrid Systems™

Technology Driven.
Environmentally Focused.

Thank You

Thanks to MathWorks for help with SimScape
Thanks to New Eagle for help with MotoHawk