Driving Simulation for the Development of Electrified Powertrains

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McMaster Automotive Resource Centre (MARC)

Transportation Electrification and Smart Mobility @ Mac

- One of the largest in academia in North America
- 400+ researchers
- $250+ million in programs & initiatives
- Unique relationships with major OEMs & Tier 1/2 suppliers
- Collaborations with private & public sector organizations

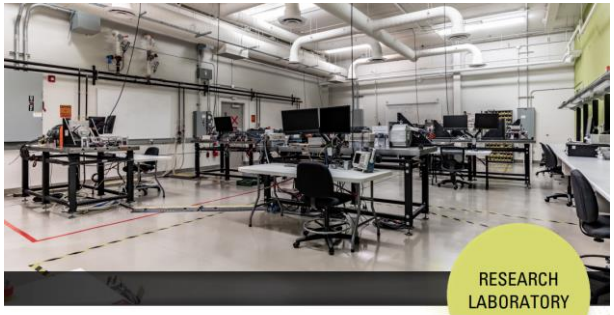
McMaster Automotive Resource Centre (MARC)

- 4 world class research groups under one roof
- Located at McMaster Innovation Park (MIP)
- 80,000 ft^2 - unparalleled in North America
- 40,000 ft^2 expansion in Q1 2022

Research and Development Areas

- Electric & hybrid vehicles
- Autonomous vehicles
- Electrified powertrains
- Electric machines
- Motor drives/inverters
- Motor controls
- Power electronic DC/DC converters
- Chargers & V2X systems
- Embedded software & controls
- Functional safety
- Energy storage systems
- Energy management systems
- Advanced driver-assistance systems (ADAS)
- Artificial intelligence & machine learning
- Thermal management
- Modeling & simulations
- **Driving simulation**
- Vehicle dynamics

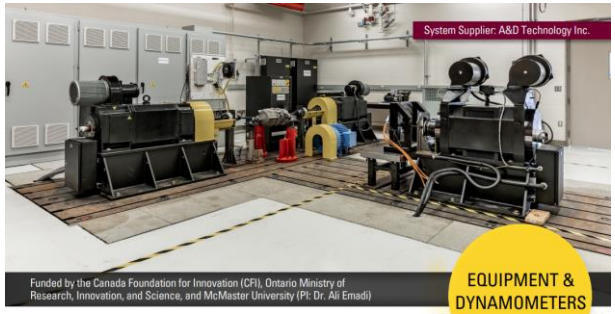
Labs and Equipment



RESEARCH LABORATORY

POWER ELECTRONICS & MOTOR DRIVES LABORATORY

MACHINES & ELECTRONICS



EQUIPMENT & DYNAMOMETERS

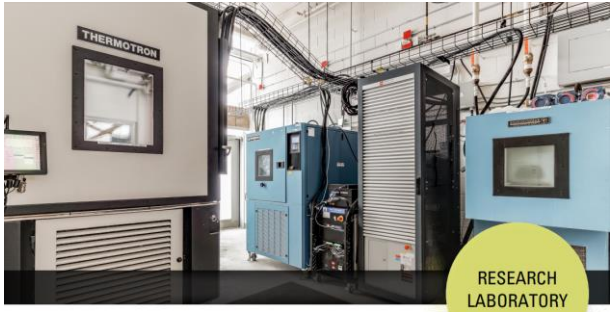
POWERTRAIN TESTER THREE MACHINE

POWERTRAIN DYNO

EQUIPMENT & DYNAMOMETERS

HIGH SPEED ELECTRIC MACHINE DYNO

ELECTRIC MACHINE DYNO



RESEARCH LABORATORY

ENERGY STORAGE LABORATORY

BATTERIES & ULTRACAPS

EQUIPMENT & DYNAMOMETERS

CHASSIS DYNAMOMETER

VEHICLE DYNO

MACHINES & EQUIPMENT

DRIVING SIMULATOR

DRIVER-IN-THE-LOOP

MARCdrive

A driving simulation lab at the McMaster Automotive Resource Centre

MARCdrive

McMaster University | ENGINEERING

BRIGHTER WORLD | CERC@MARC

Powertrain System Development

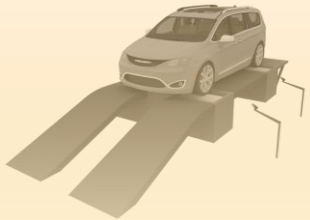
Powertrain System Development

Traditional Approach

- Simulation
  - Performance requirements
  - Architecture selection
  - Initial sizing
  - Offline optimizations

Virtual Development

- Experimental
  - In-lab experiments
    - Roller-bench, dynamometers
  - Drive cycles
    - Urban, highway, mixed
  - Off-lab experiments
    - Calibration, reliability

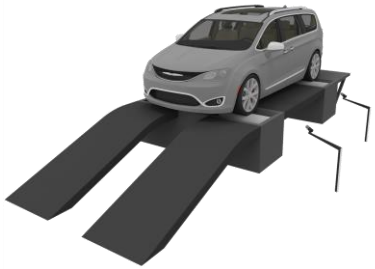


Physical Development

Powertrain System Development

Traditional Approach

Virtual Development



Physical Development

Model-in-the-loop

Software-in-the-loop

Software-in-the-loop

Driver-in-the-loop

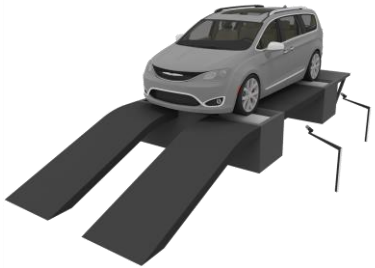
Hardware-in-the-loop

Powertrain System Development

Adding Driving Simulation

Virtual Development

Driving Simulation



Physical Development

Model-in-the-loop

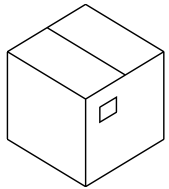
Software-in-the-loop

Driver-in-the-loop

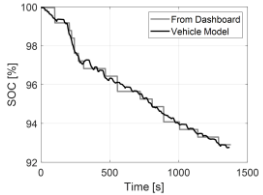
Hardware-in-the-loop

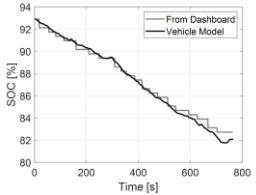
Powertrain System Development

Methodology

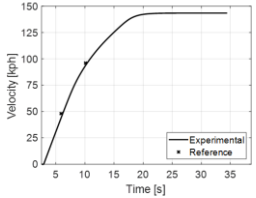


Consumption:





Performance:



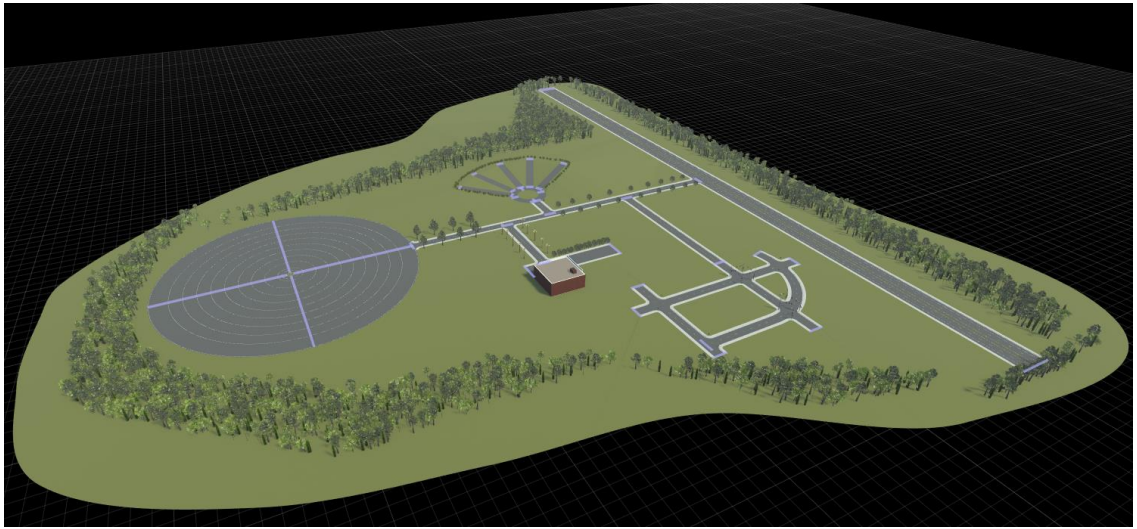
"Package"

- Hybridization pack
- Component
- Control method
- Calibration

Powertrain System Development

Testing Environments

- Proving ground created on VI-WorldSim
  - Hills
  - Straights
  - Circles
  - Mock-up city
  - …



Powertrain System Development

Testing Environments

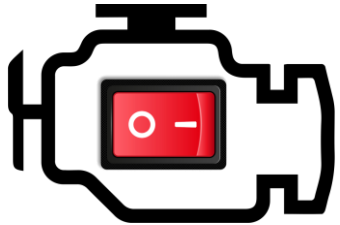
- Diverse scenarios created on VI-WorldSim
  - Urban environments
  - Highway environments
  - Standard roads
  - Digital twins

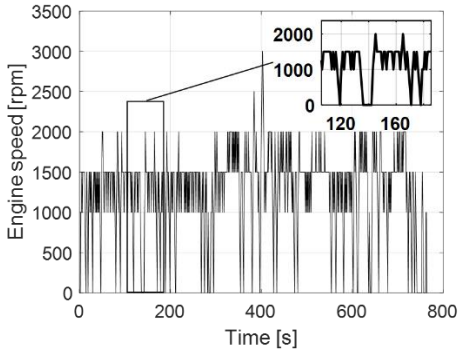
Drive-before-build

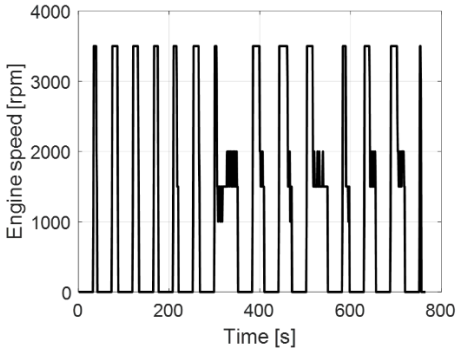
Drivability

Engine Operation

- Start-to-idle time
- Reducing number of events
- Spacing events
- Mean dwell time (sensitivity analysis)
- Promote max efficient operation

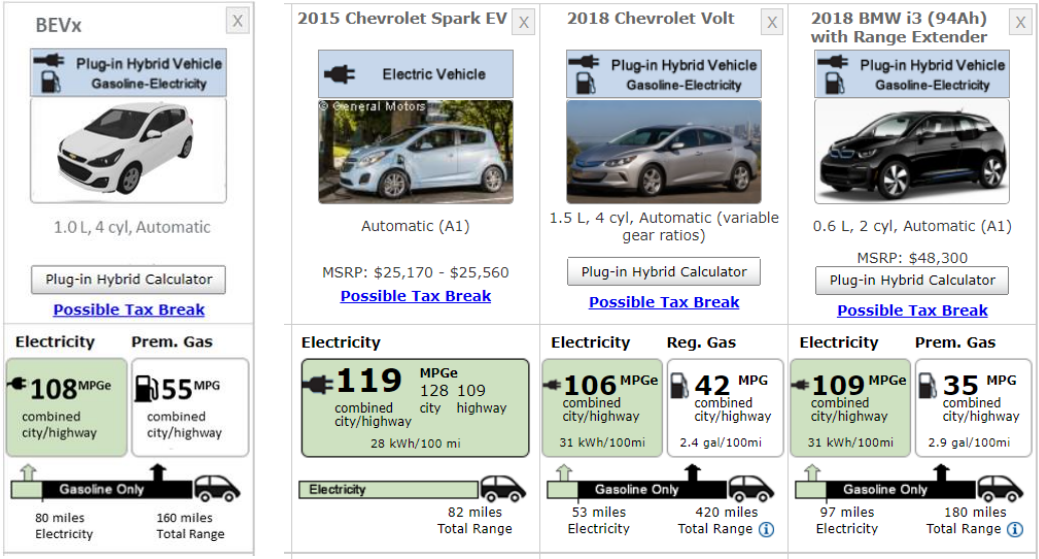






Drive-before-build

Consumption Results



Conclusions

Driving simulation is a powerful tool for defining a product's strategy.

It allows a comprehensive analysis of proposed modifications that includes drivability, performance, and consumption.

In addition, it enables human-centric design and driver-in-the-loop calibration of systems.

Moving Forward

Multi-modal Design

Model-in-the-Loop

Sizing of the components based on usage cycles and expected economy

Software-in-the-Loop

Introduction of software strategy and control variables to achieve performance, economy and drivability

Multi-modal design means connecting all four aspects of the development process

Driver-in-the-Loop

Calibration of the controls based on driver's perception on digitalized environments

Hardware-in-the-Loop

Validation of the controls on test-bed platforms using complete or partial prototypes

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