Using Hardware-in-the-Loop Simulations to Improve EPA Emissions Testing

John Consiglio
The Cooper Union
February 24, 2009

Engine Testing Basics

Real World-

Most realistic, uncontrolled environment, high cost

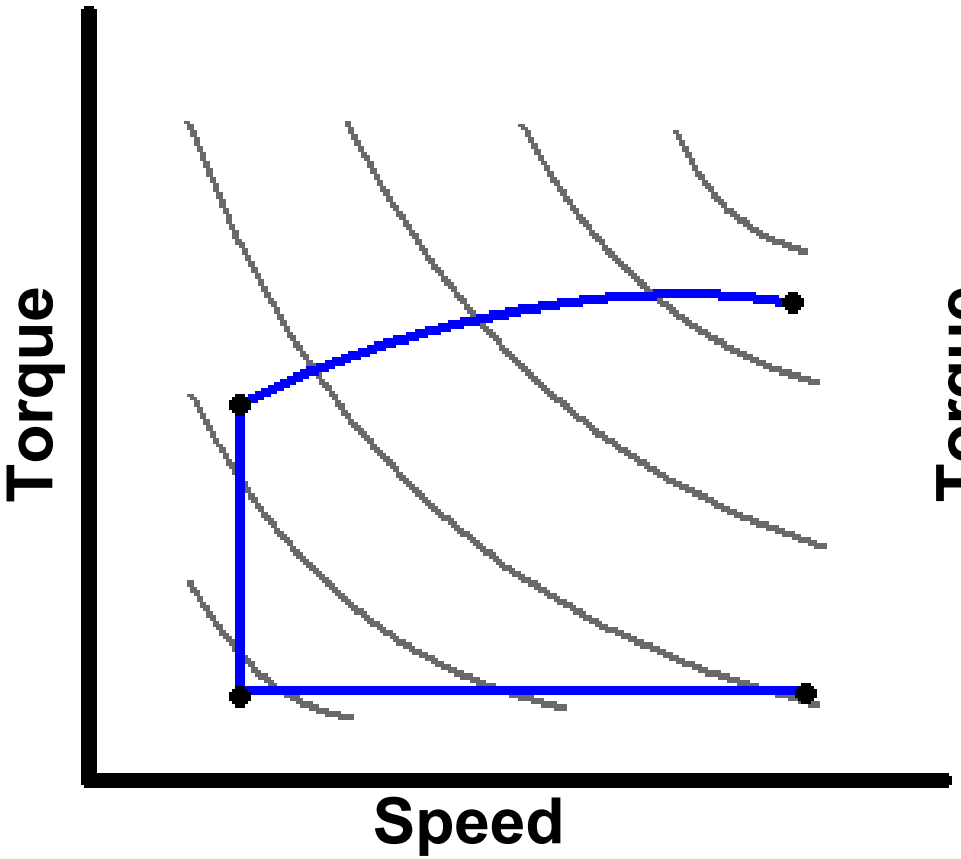
Simulated-

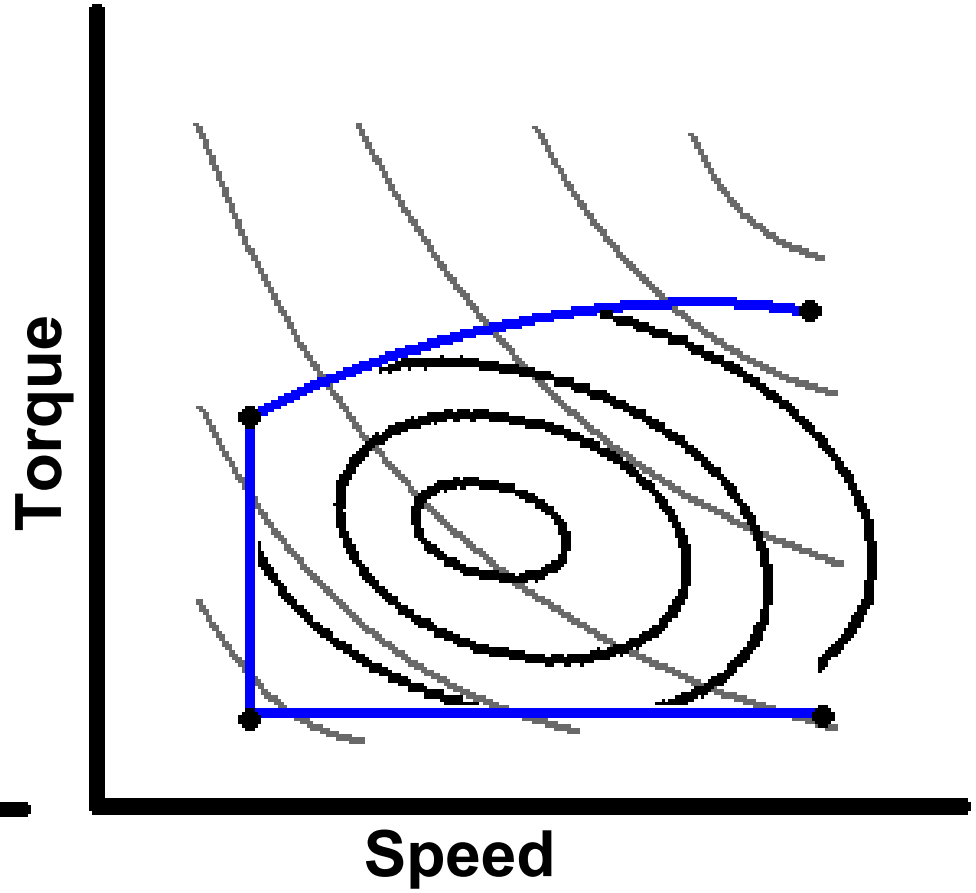
Low cost, quick results, not always valid

HIL Testing-

Combined simulation and real world design screening environment

Engine Testing Basics





Motivation and Background

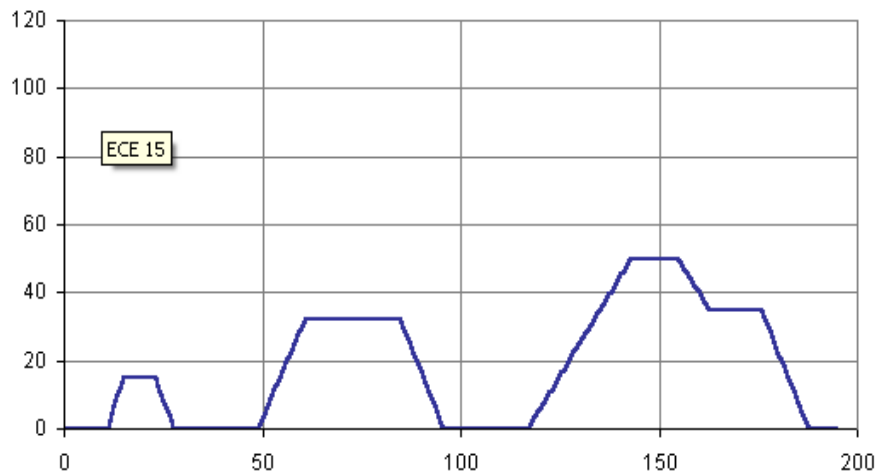
Powertrain Testing Basics

Important specific terminology

Road Load

$$F = F_{Aero} + F_{Tires} + F_{Road\ Slope} + Ma$$

- **Driving Cycle**



- **Engine Dyno vs. Chassis Dyno**

Motivation and Background

Powertrain Testing Basics

The EPA FTP-75 Emissions test: Driving Cycles

Outline

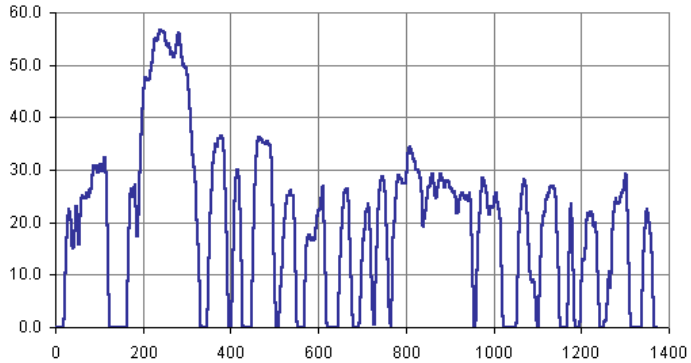
Motivation and Background

EPA FTP-75 Test

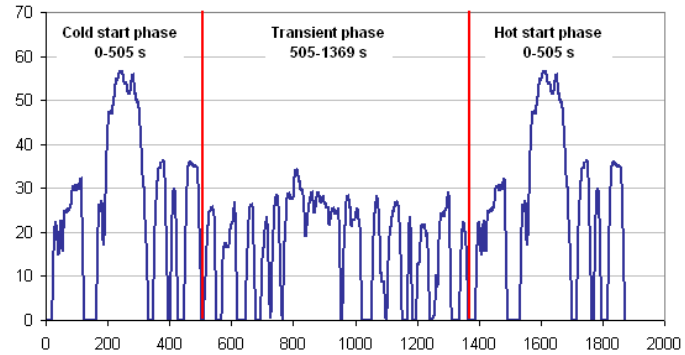
System Design

Some Results

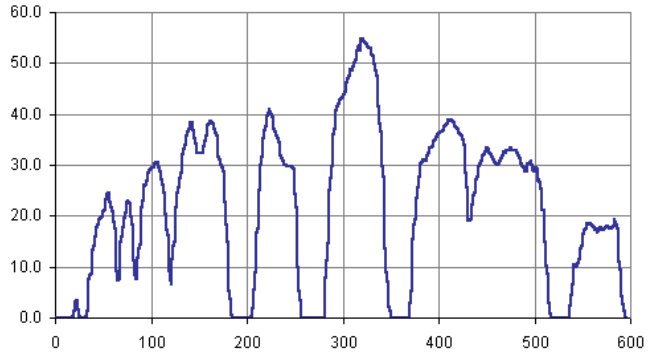
FTP-72 test

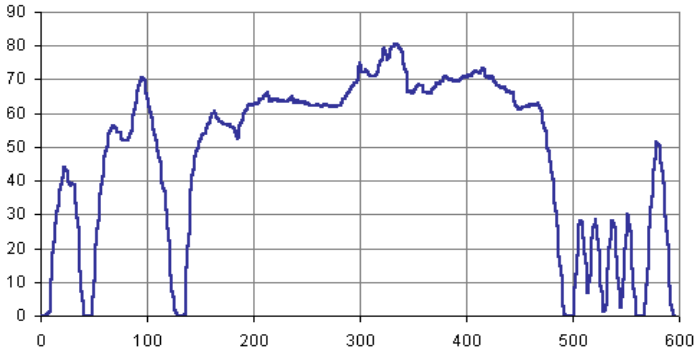


Addition of Hot Start,1990



SFTP tests introduced in 2000





Motivation and Background

Powertrain Testing Basics

Outline

Motivation and Background

Powertrain Testing Basics

System Design

Some Results

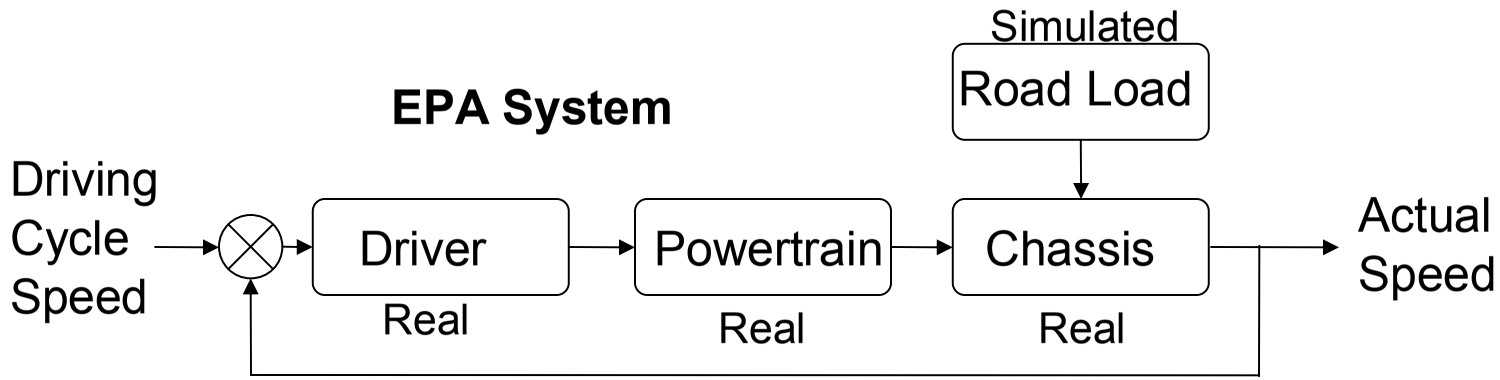
Basic Equipment Overview

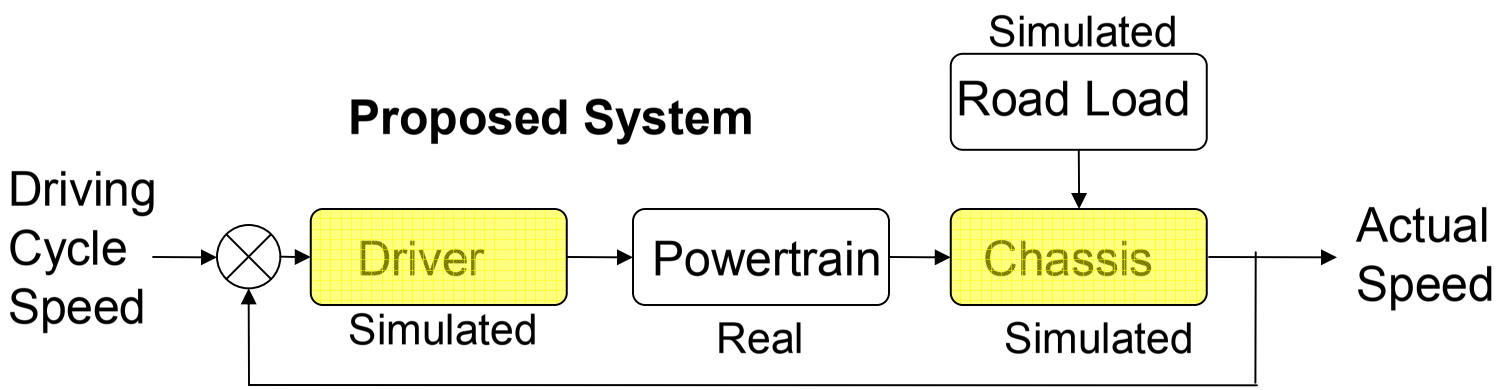
1. Powertrain, Engine/Transmission
2. Power Absorption Unit (load)
3. Measurement and Control Systems

System Design

Goals of new system

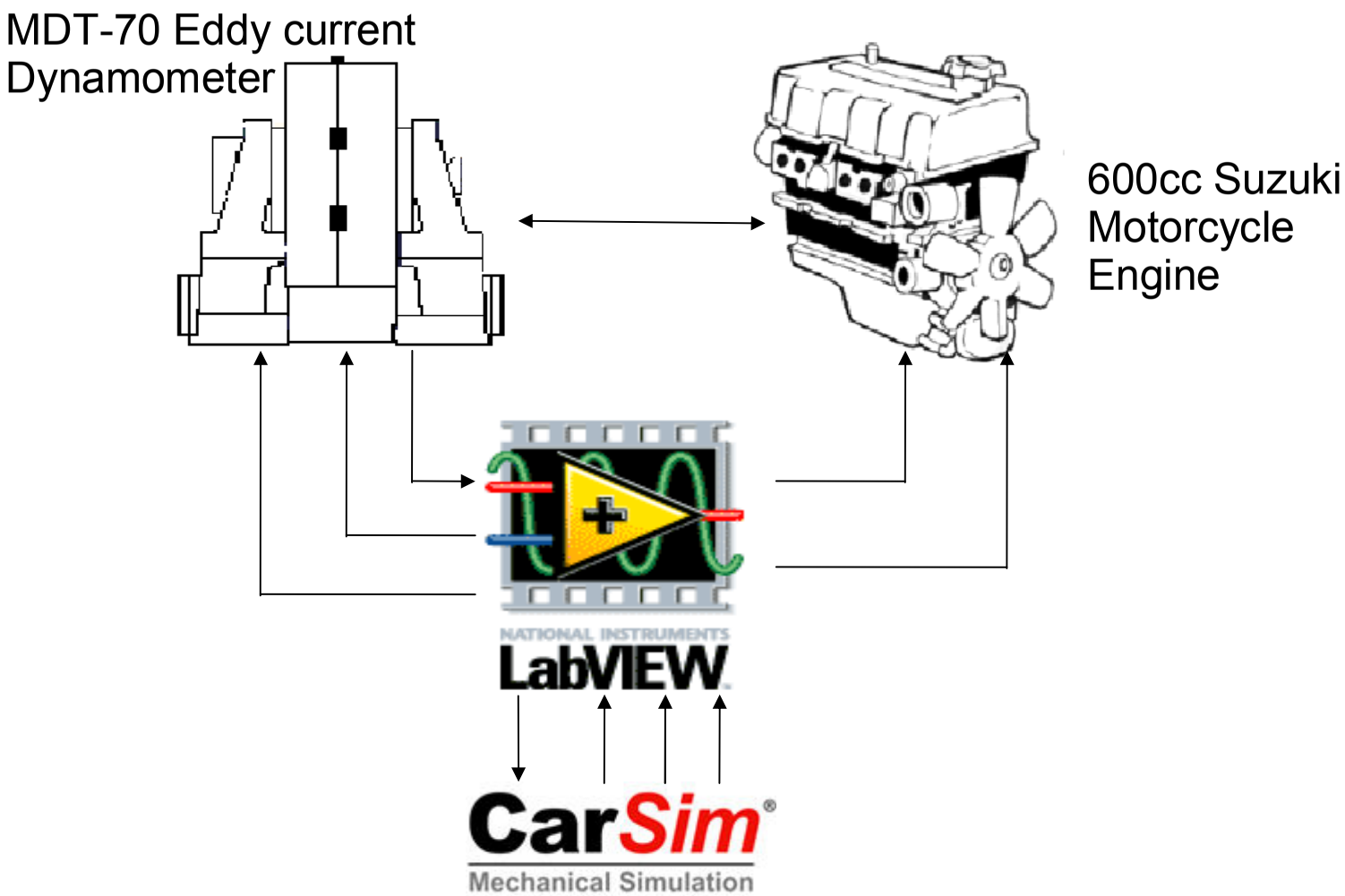
Proposal for new testing system





System Design

System Components

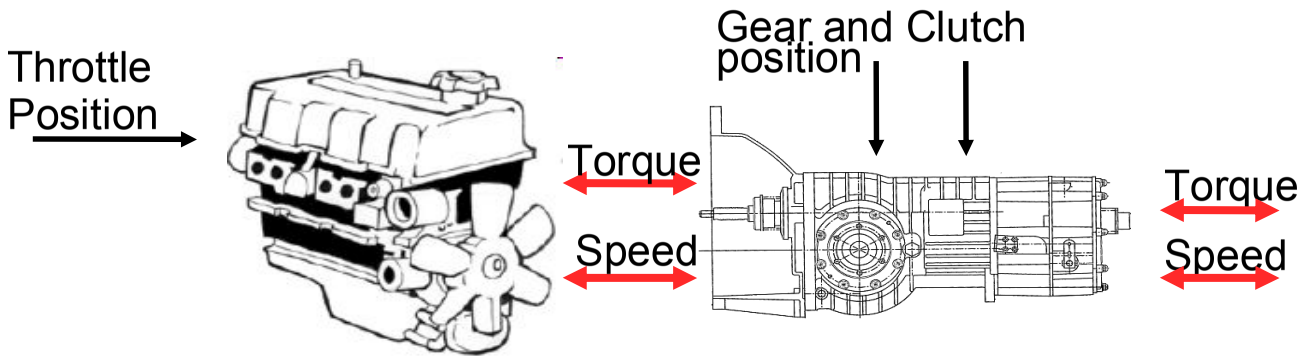


Outline
Motivation and Background
System Design
System components
Some Results

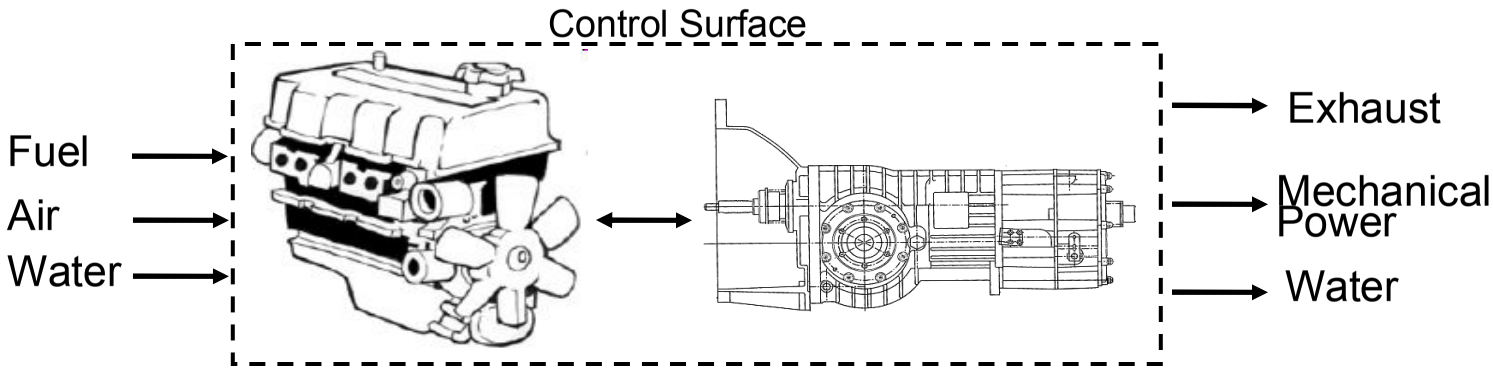
Motivation and Background

Powertrain Testing Basics

Basic Equipment : Powertrain



Powertrain as a mechanical system



Powertrain as an open thermodynamic system

System Design

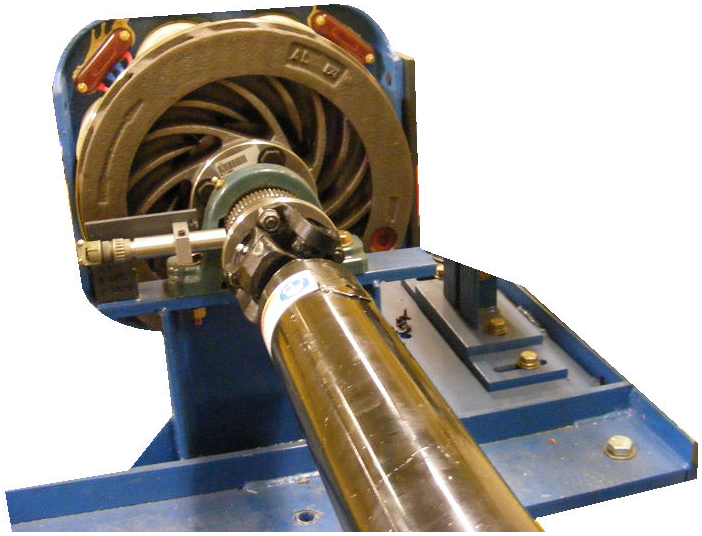
System Components: Dynamometer

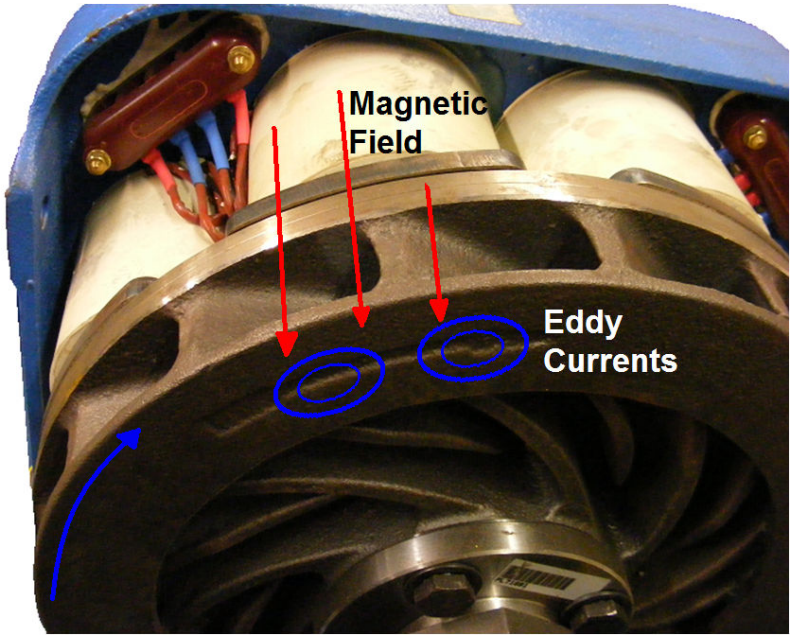
Eddy Current Dynamometer

-Creates torque by moving conductor through magnetic field

-Advantages: Little to no wear, low inertia, fast simple control

-Disadvantages: Cannot develop torque, poor cooling

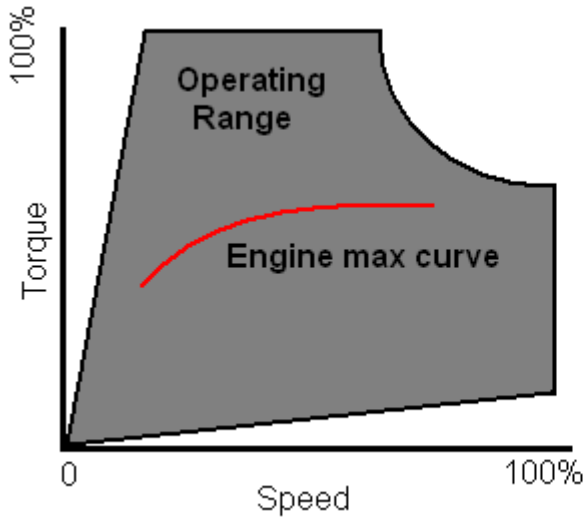


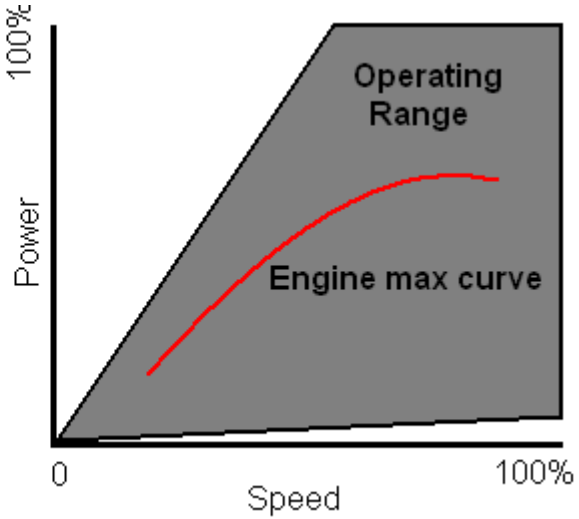


System Design

System Components: Dynamometer

Eddy Current Dynamometer, Performance curves





Eddy current cannot create max torque at low RPM

Engine max torque and power curves must be within dyno operating range

System Design

System Components: CarSim

Outline

Motivation and Background

System Design

CarSim

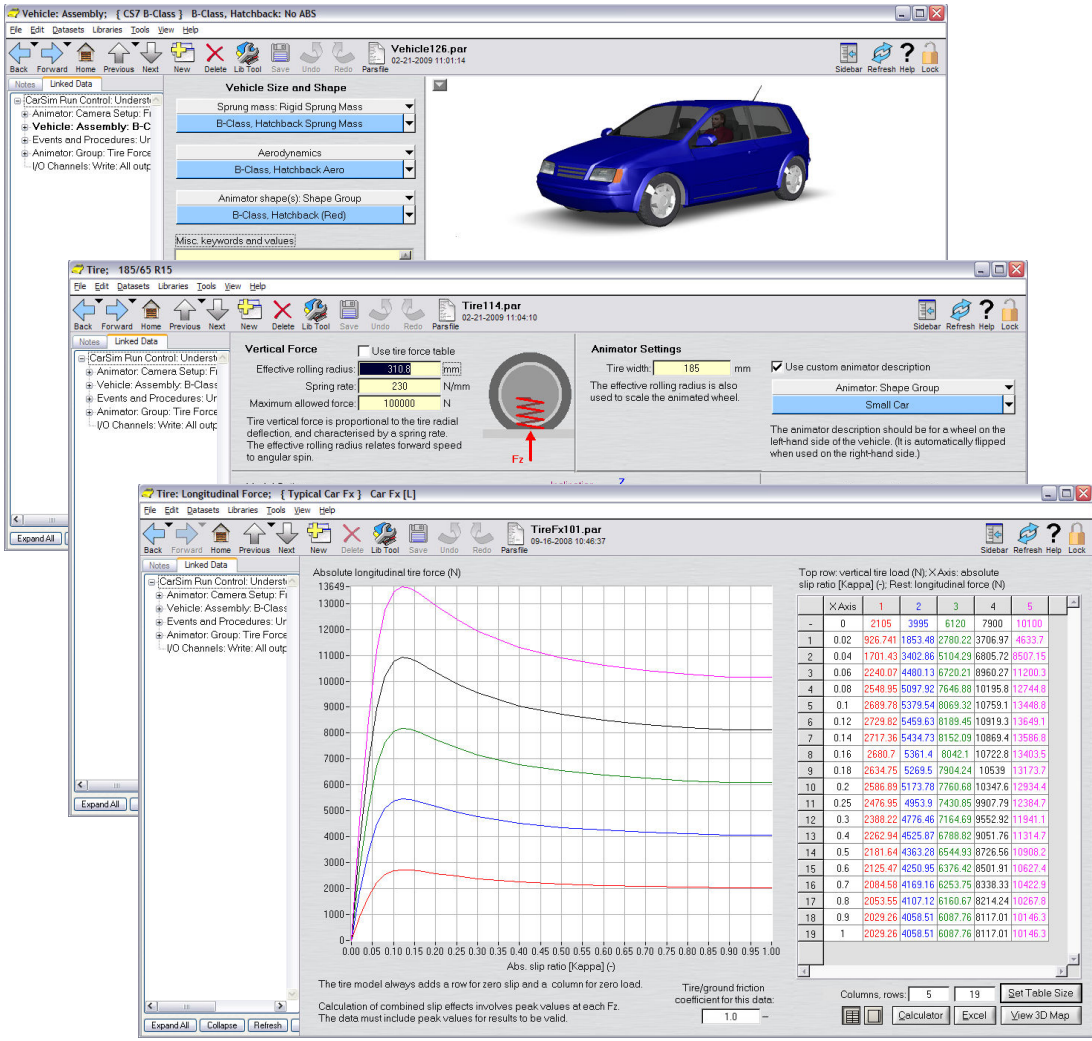
Some Results

Vehicle model

- Suspension
- Tires
- Aerodynamics

Solver

- Differential equations of motion
- Numeric solver



System Design

System Components: CarSim

Outline

Motivation and Background

System Design

CarSim

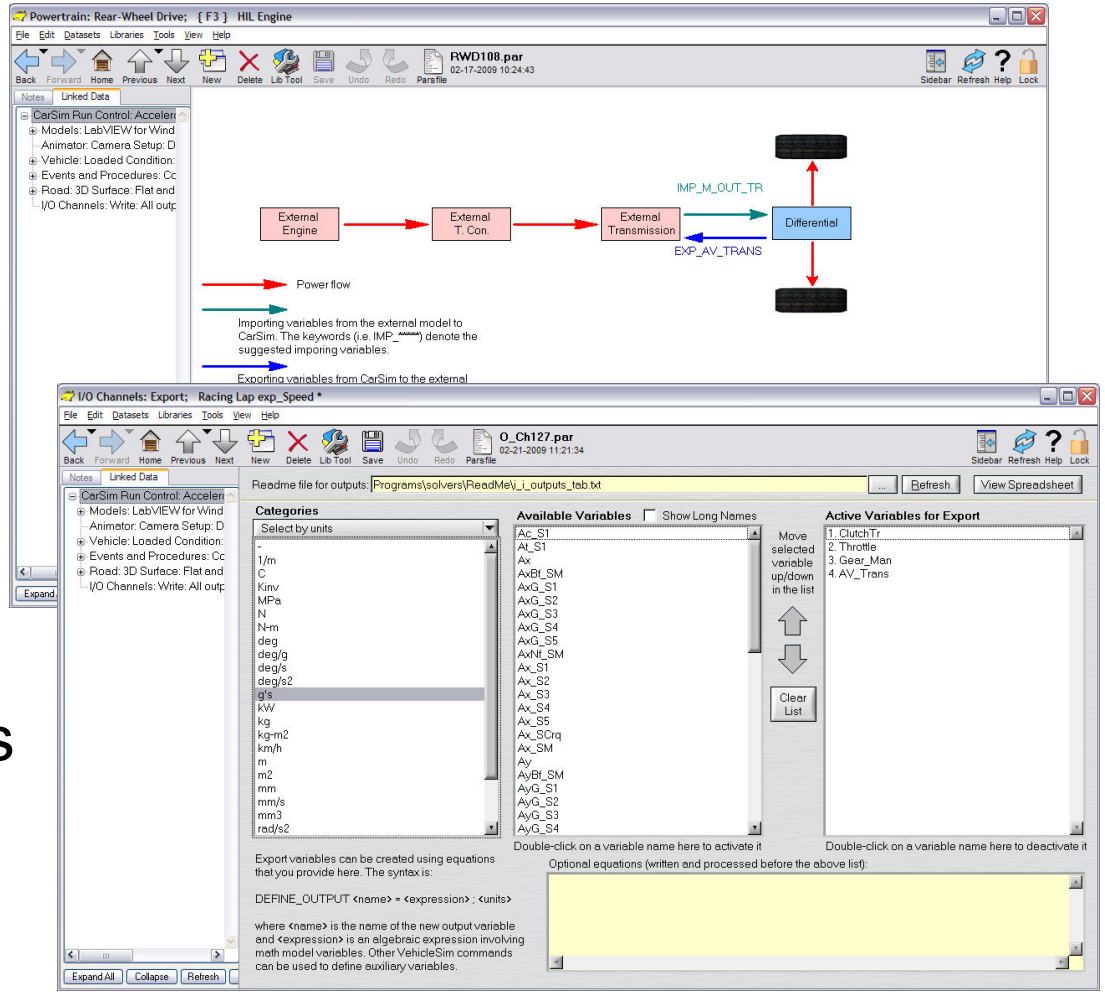
Some Results

Import/Export

- Powertrain
- Driver model
- Tire Model

.HIL Examples

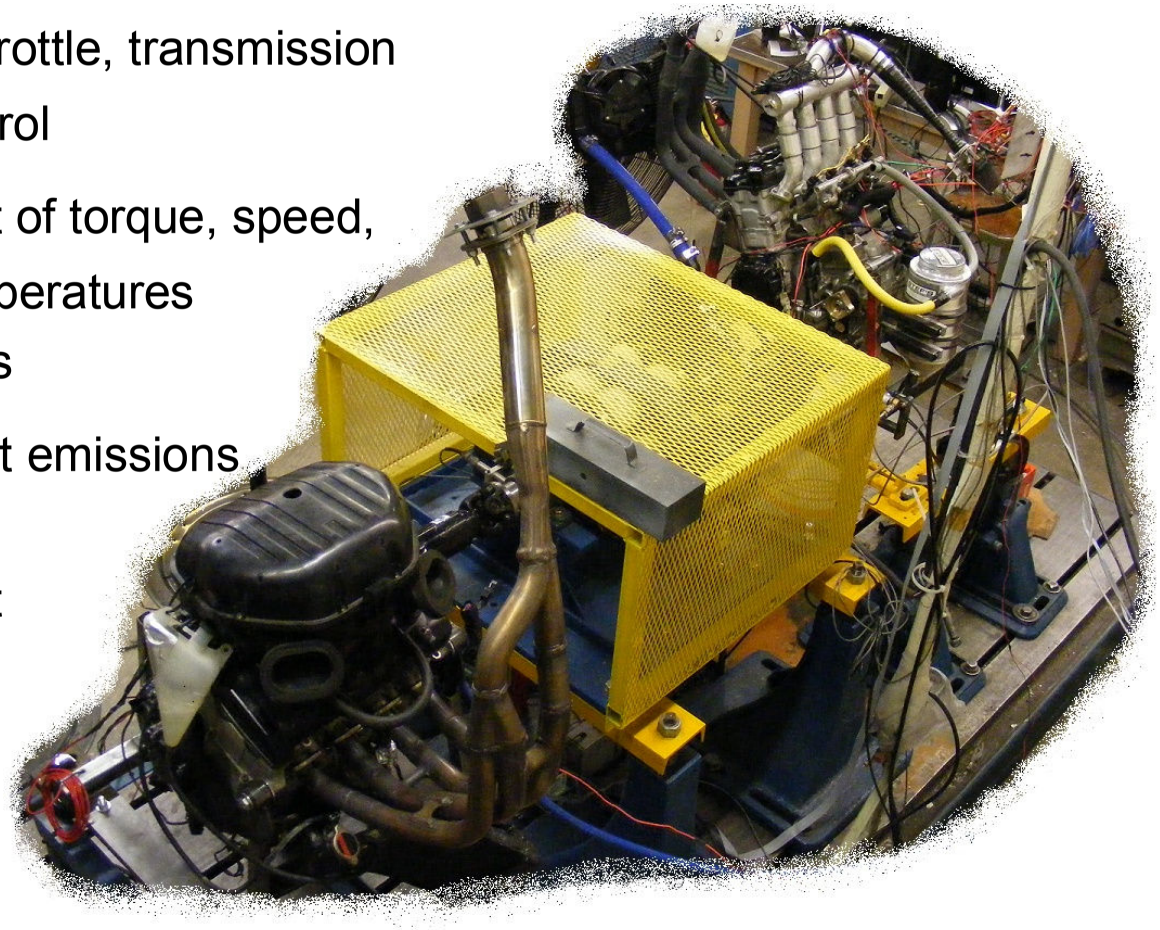
- ABS/TCS
- Engine Control
- Shift Schedules



System Design

System Components: Measurement and Control

- Automated throttle, transmission and load control
- Measurement of torque, speed, fuel flow, temperatures and pressures
- Many different emissions collection and measurement methods



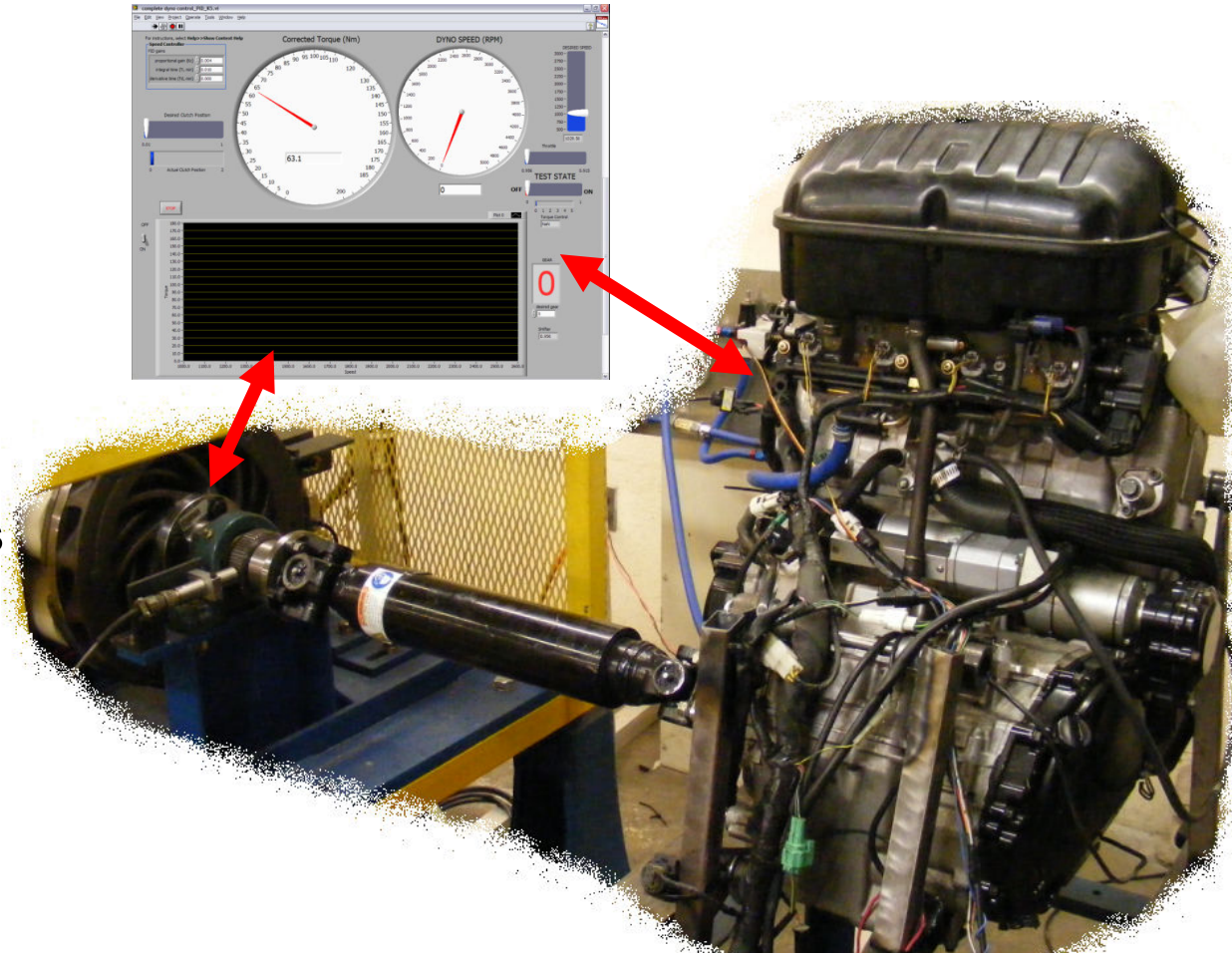
System Design

System Components:

Measurement and Control

Software simulates road loads and driver inputs and sends controls to test stand.

Speed and torque measurements are taken and used as inputs to simulation.



System Design

System Components: LabView

Outline

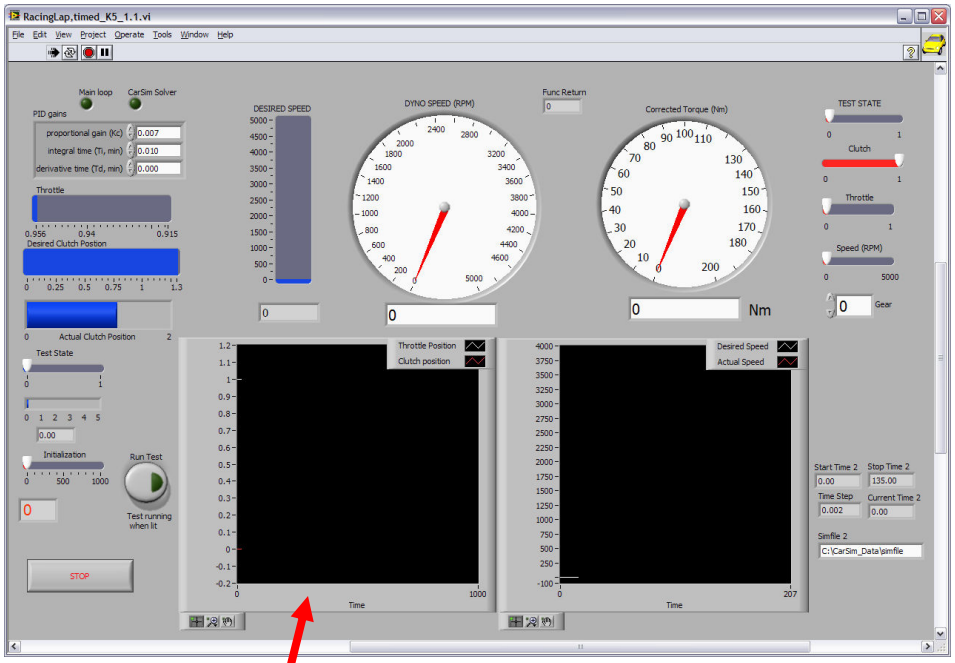
Motivation and Background

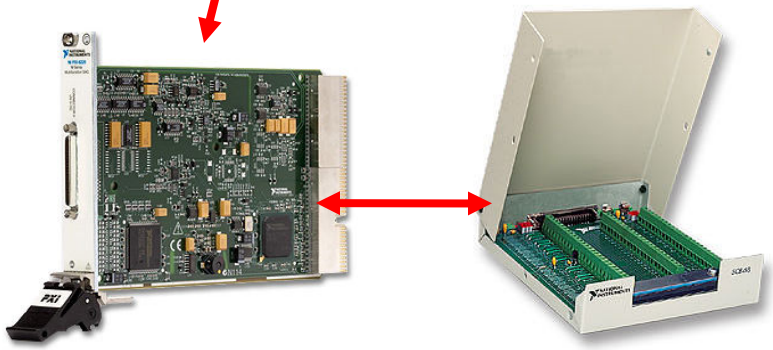
System Design

LabView

Some Results

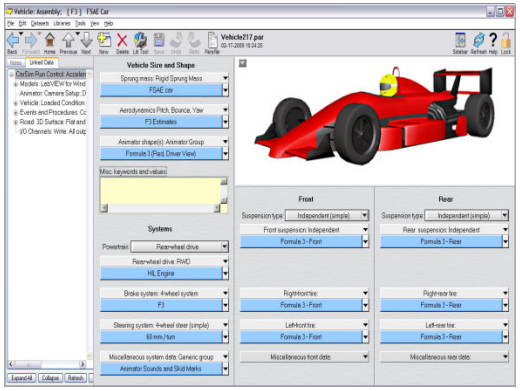
- LabView allows graphical programming of measurement and control systems
- Uses the CarSim DLL solver with imports and exports
- Data is sampled at 25Hz, CarSim solver runs at 1kHz
- 16bit, 250kHz Data acquisition card



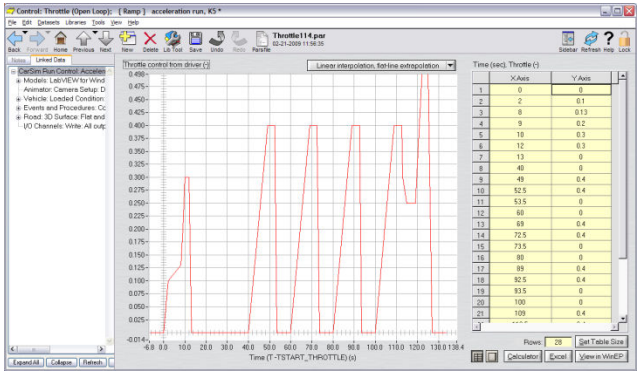


Results

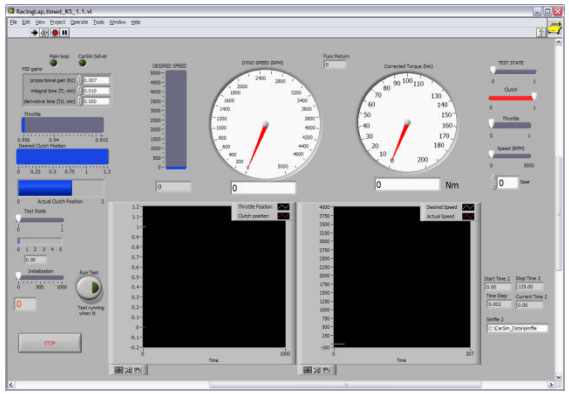
Test Procedure



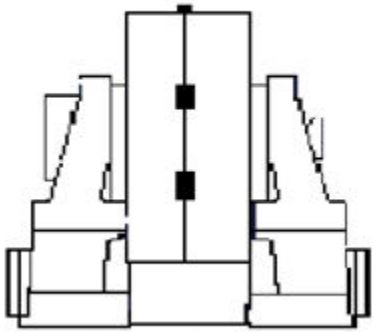
1) Create vehicle model

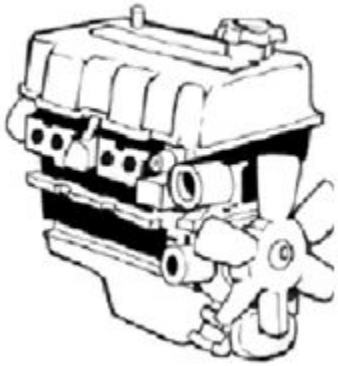


2) Create driving cycle



3) Export to LabView

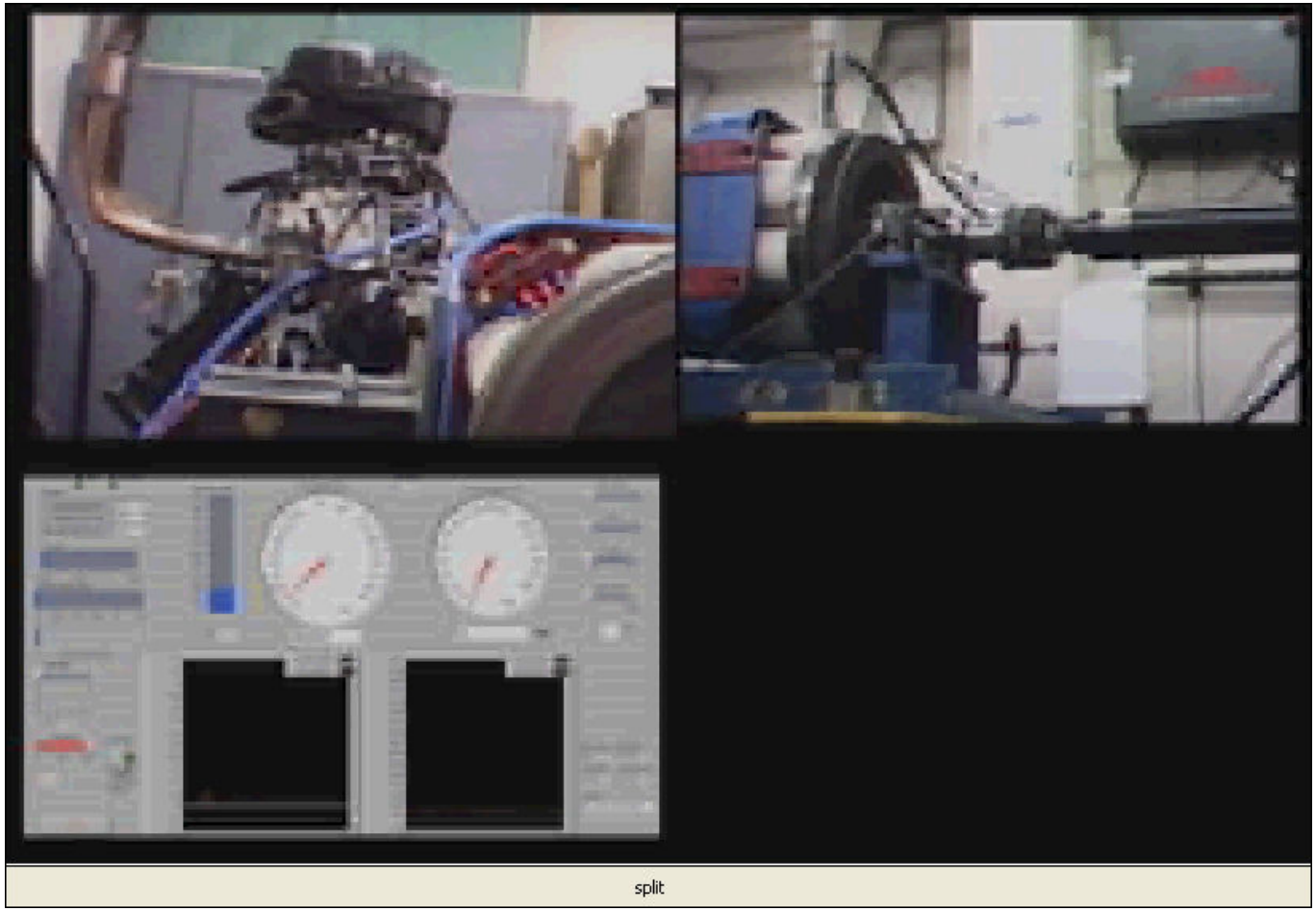




4) Run in real time with powertrain

Results

Example driving cycle



Conclusions and Further Work

-Testing system that combined real world and simulations

-System for early design screening

-Future emissions and efficiency studies

-Development of new driving cycles