Integration Of Control System Components For Optimum Engine Response

Detroit Diesel Corporation

Marc Allain

Craig Savonen

Outline

- Engine Control Requirements
- Control System Components
- Specific Challenges
- Sensors & Actuators
- Next Generation Control Logic

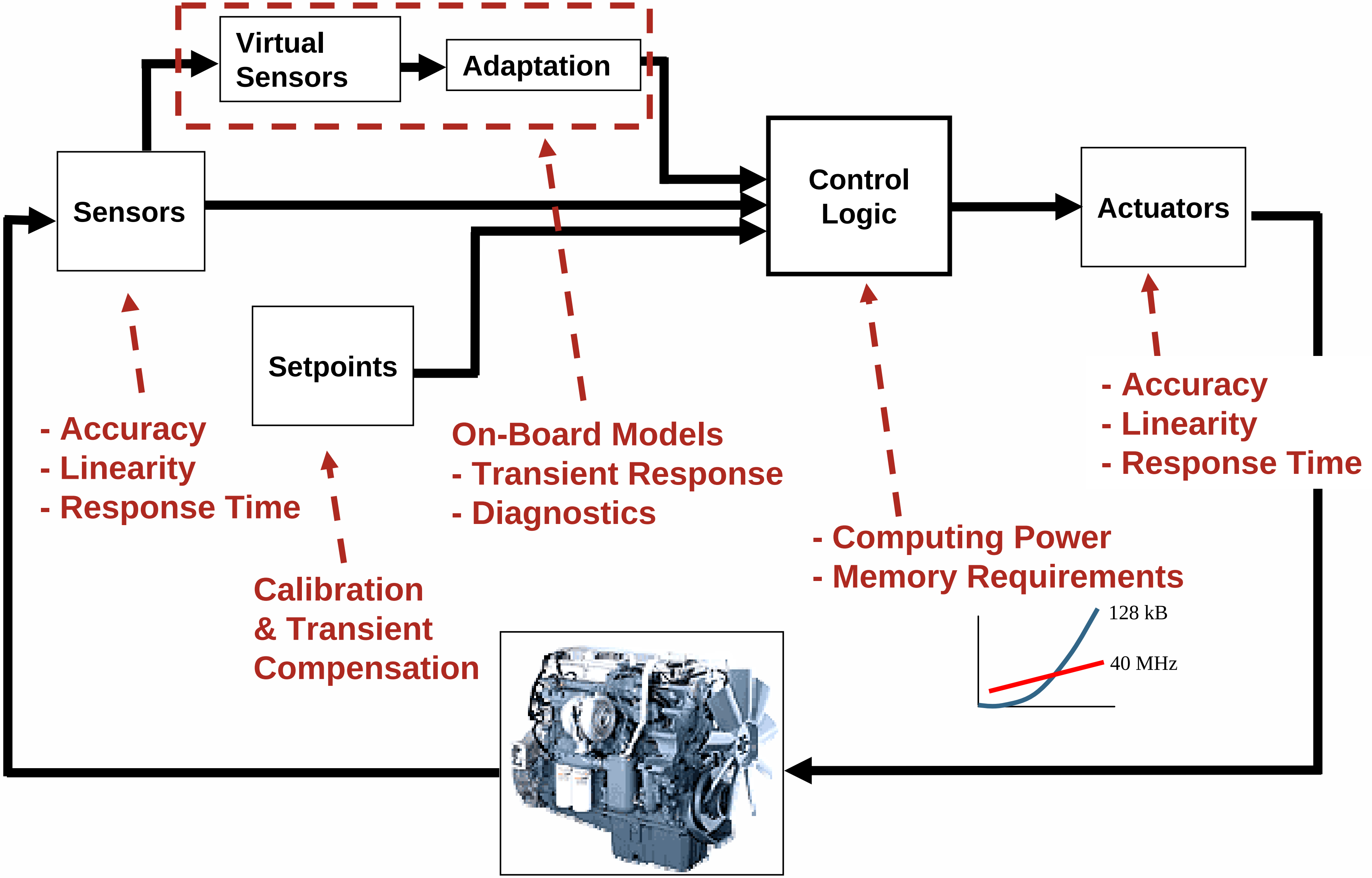
Engine Design Requirements – 2010 & Beyond

- Improve Drivability and Fuel Economy
- 90% Emissions Reduction Compared to 2006
- 435,000 Miles Useful Life -- Customer's Expectation > 1 Million Miles
- Under-The-Hood Operating Temperatures: -40 ^{o}C to +120 ^{o}C
- Altitude: Up to 12000 ft

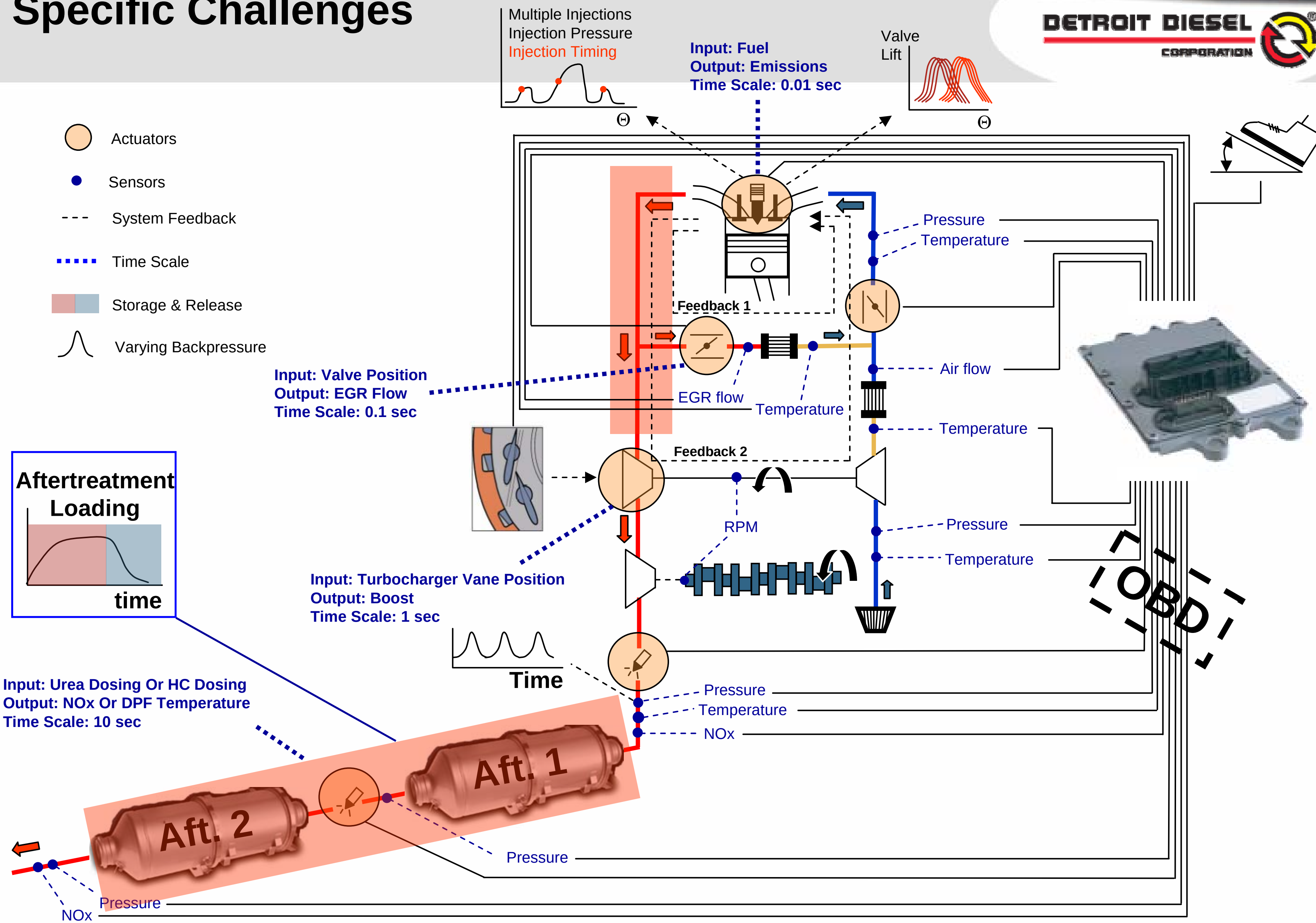
Engine Control Requirements – 2010 & Beyond

- **Flawless Steady-State Stability**
- **Improved Transient Response**
- **Reduced Variability**
- **Increased Diagnostics Capability**

Control Components



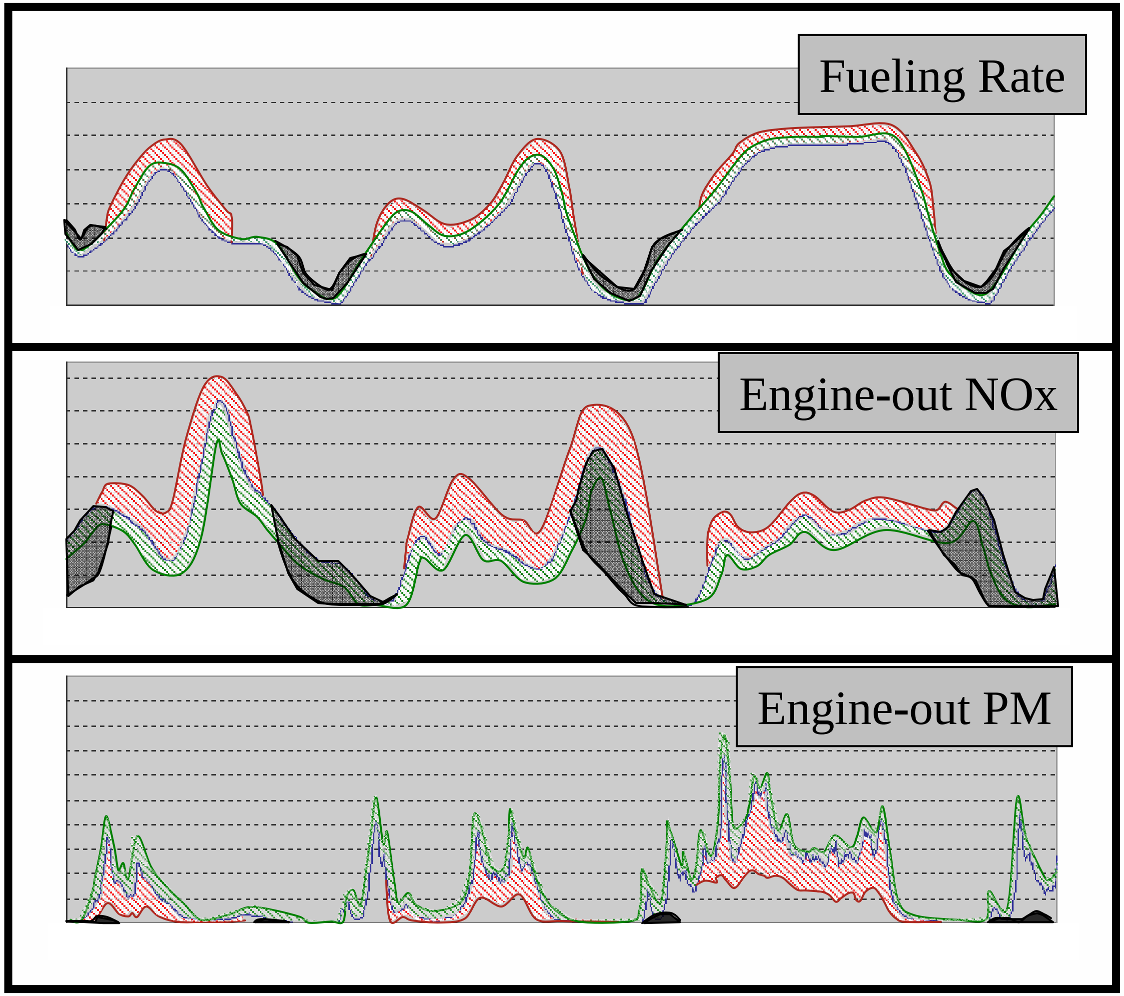
Specific Challenges



Specific Challenges – Calibration

Baseline – No Aftertreatment
Scenario 1
Scenario 2
Scenario 3

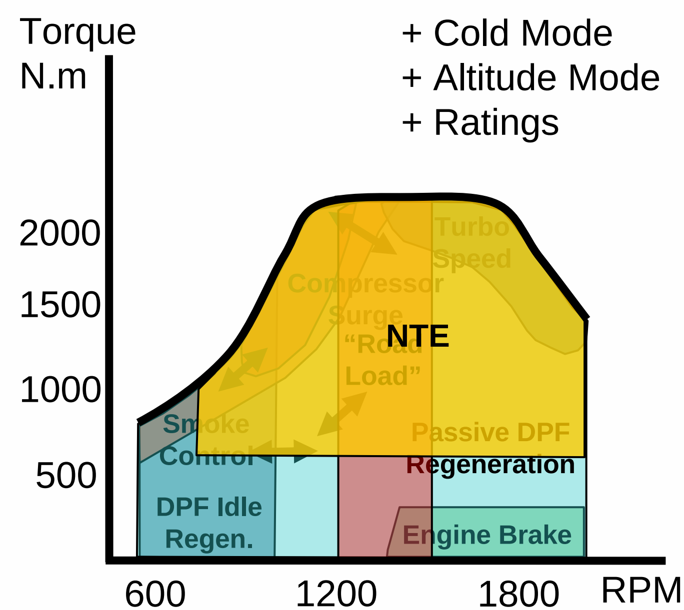
With NOx & PM Aftertreatment
Same Tailpipe-out Emissions



Optimum Engine Response:

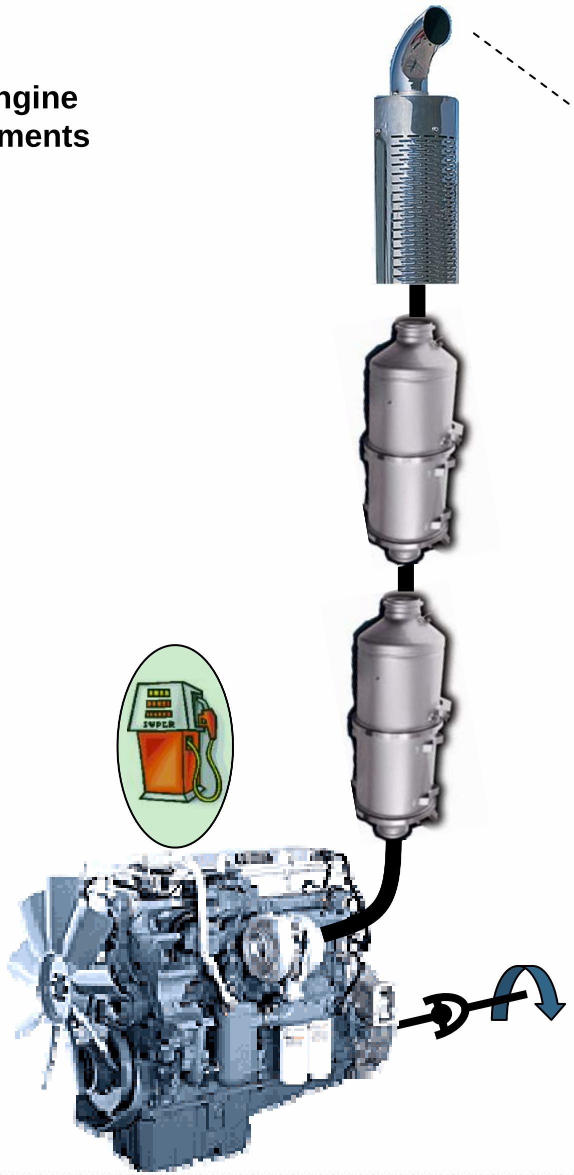
Take Advantage Of Added Flexibility Through:

- Calibration Optimization
- Transient Controls



Sensors

Basic Engine Requirements

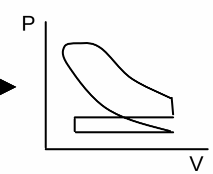


Tailpipe-out NOx
Tailpipe-out PM

- Resolution
- Precision
- Humidity
- Durability

NOx & Cylinder Pressure Sensors Enable Improvements In Engine Control

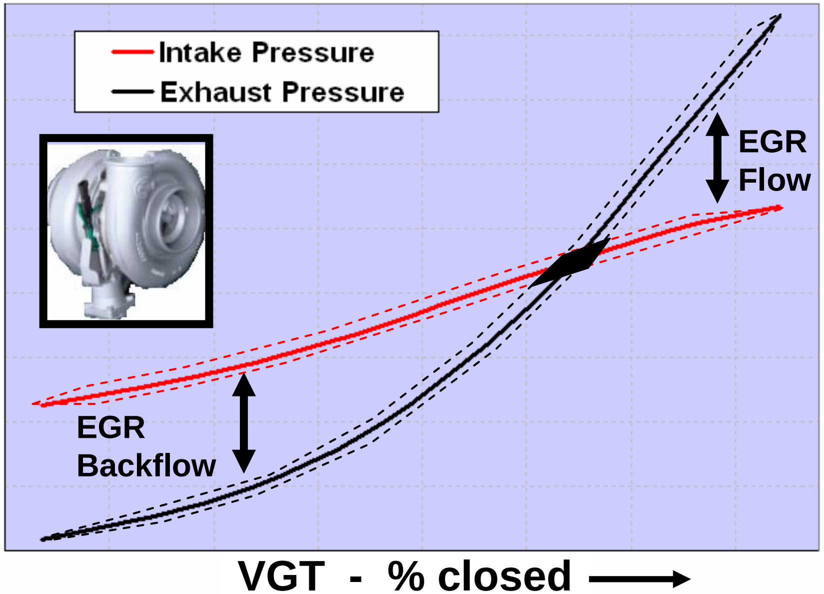
Cylinder Pressure Sensors



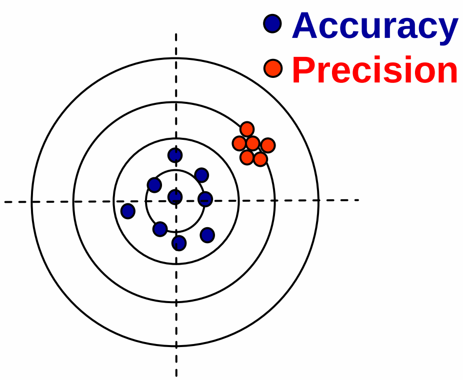
OBD & HCCI
- Comb. Quality
- Misfire Detection
- Load Control

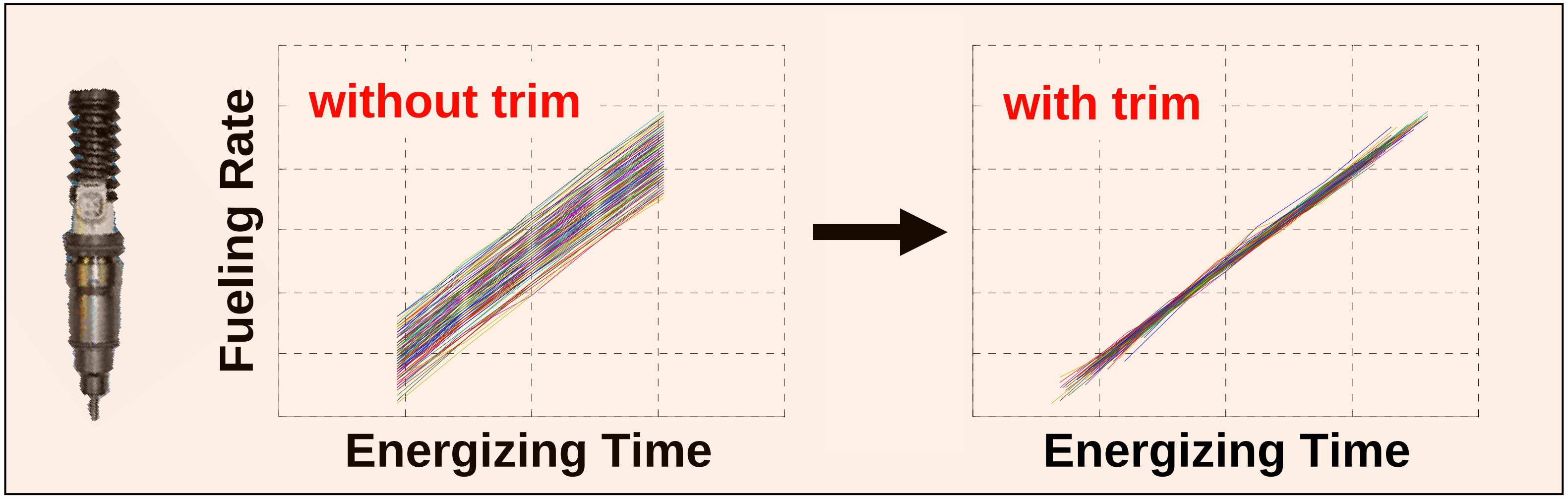
Torque

Actuators Performance – Accuracy, Linearity, Response Time



Actuator Internal Position Feedback & Trim Significantly Reduce Emissions Variability

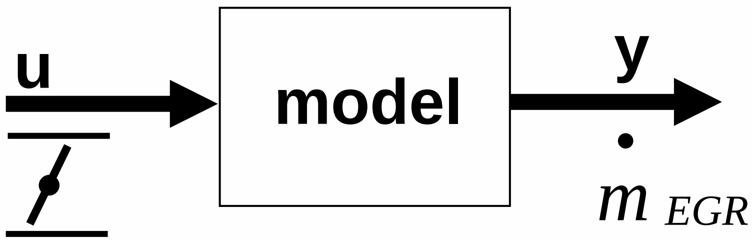


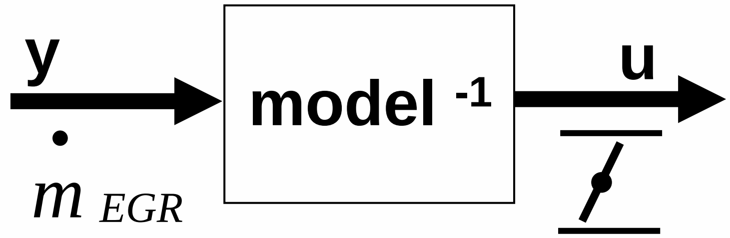


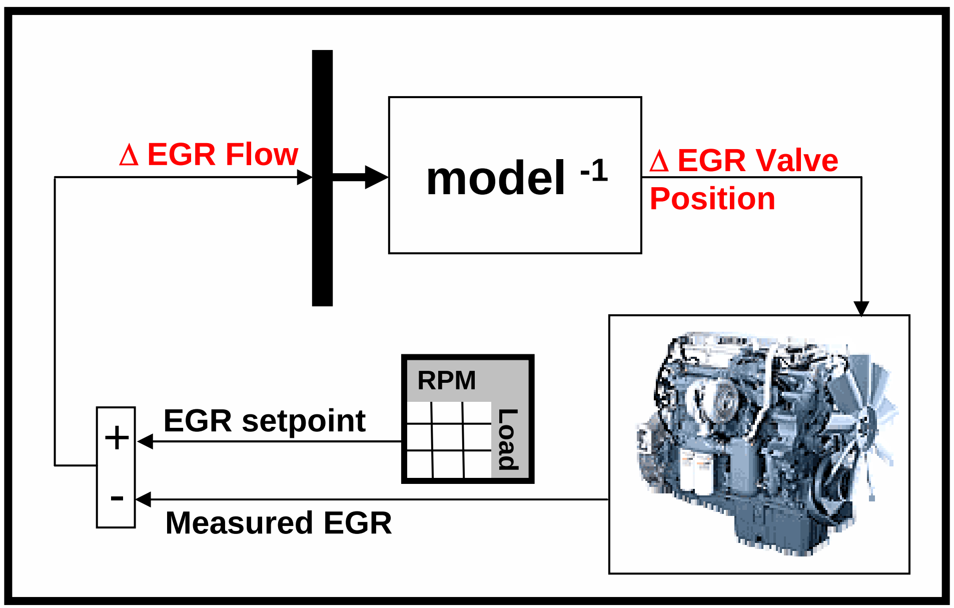
Control Logic –
Closed-Loop Model-Based Control

- Why Closed-Loop?
  - Reduce System's Sensitivity To Variations
  - Control Transient System Response
- Downside
  - Risk Of Instability
  - Computing Requirements
- Why Model-based?
  - Ability To Anticipate System Response

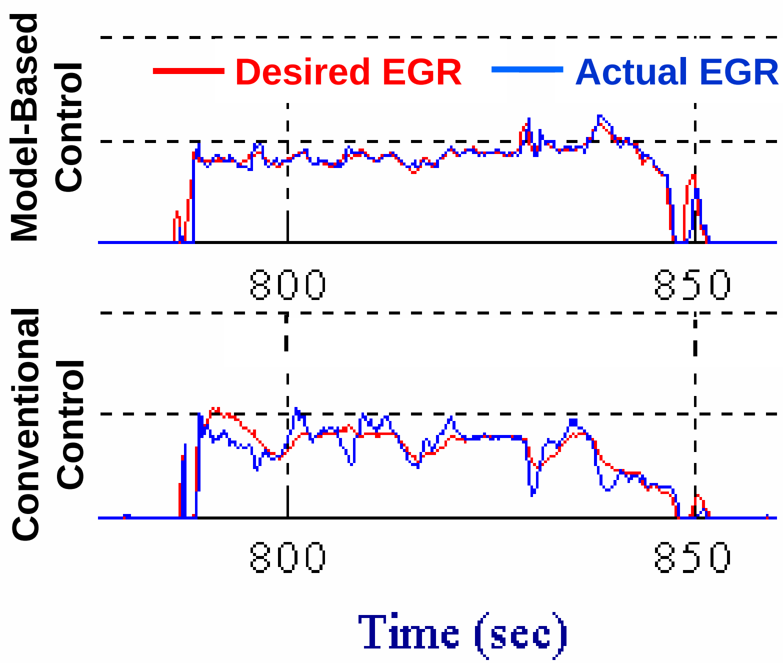
Illustration: Model-Based Control



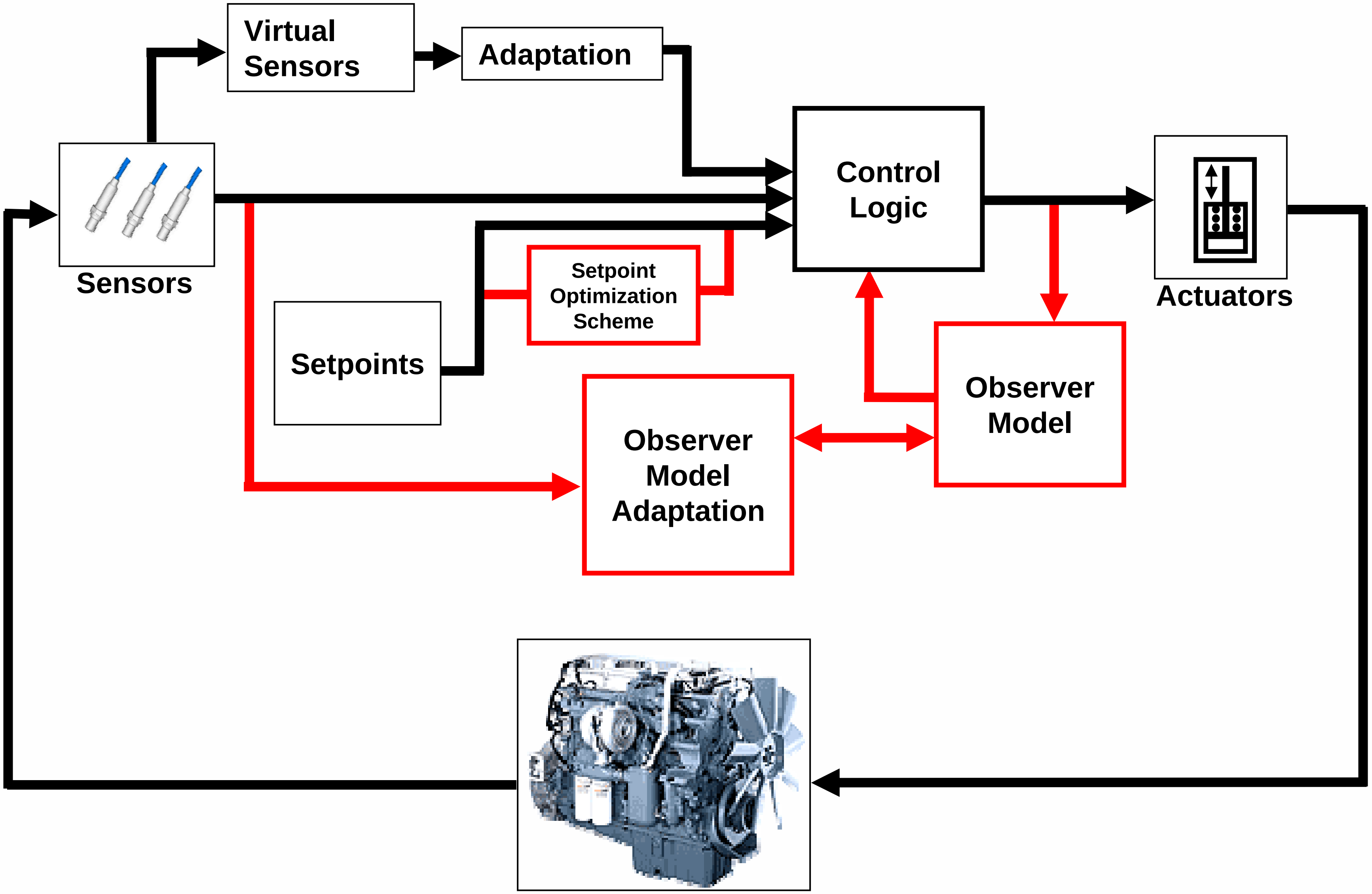




Model-Based Control System



Next Generation Controls



Conclusions

- **Added Hardware Flexibility Translates Into Added Calibration & Control Complexity**
- **Aftertreatment Dynamics Differ Significantly From Other Engine Systems**
- **Traditional Engine Control Techniques Rendered Impractical By The Number Of Feedback Loops**
- **Model-Based Techniques Simplify Engine Control By Constraining Specific Degrees Of Freedom**
- **Calibration Optimization Is Becoming The Most Challenging Area Of Controls Development**