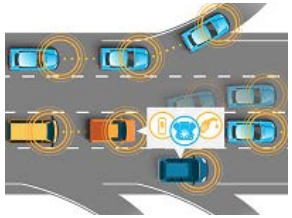
Fuel Economy Optimization with Dynamic Skip Fire in a Connected and Automated Vehicle

The Ohio State University (Lead)
Delphi Automotive Systems, LLC
Tula Technology Inc.
Transportation Research Center Inc.

PI: Dr. Giorgio Rizzoni



Team

THE OHIO STATE UNIVERSITY
CENTER FOR AUTOMOTIVE RESEARCH

Background:
The Center for Automotive Research (CAR) is an Inter-disciplinary Research Center in the OSU College of Engineering, with a focus on sustainable mobility

Role:
Develop integrated control strategies for optimal powertrain operation leveraging connected and automated vehicle (CAV) technologies

PIs: Giorgio Rizzoni, Marcello Canova, Abhishek Gupta, Levent Guvenc

Program Manager: Greg Busch

TULA

Background:
Small, dynamic, innovative company with a focus on improving the efficiency of internal combustion engines

Role:
Optimize Dynamic Skip Fire (DSF) operation in a mild-hybrid vehicle with inputs from CAV technologies

PI: Mark Wilcutts

DELPHI

Background:
Global Tier 1 automotive supplier with industry-leading experience CAV technologies and engine management systems

Role:
Integrate CAV, 48V mild hybrid and DSF technologies onto a demo vehicle, and provide optimized, production-level powertrain controls.

PI: Pete Olin

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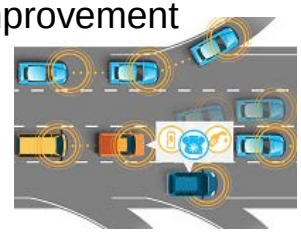
TRC Transportation Research Center Inc.

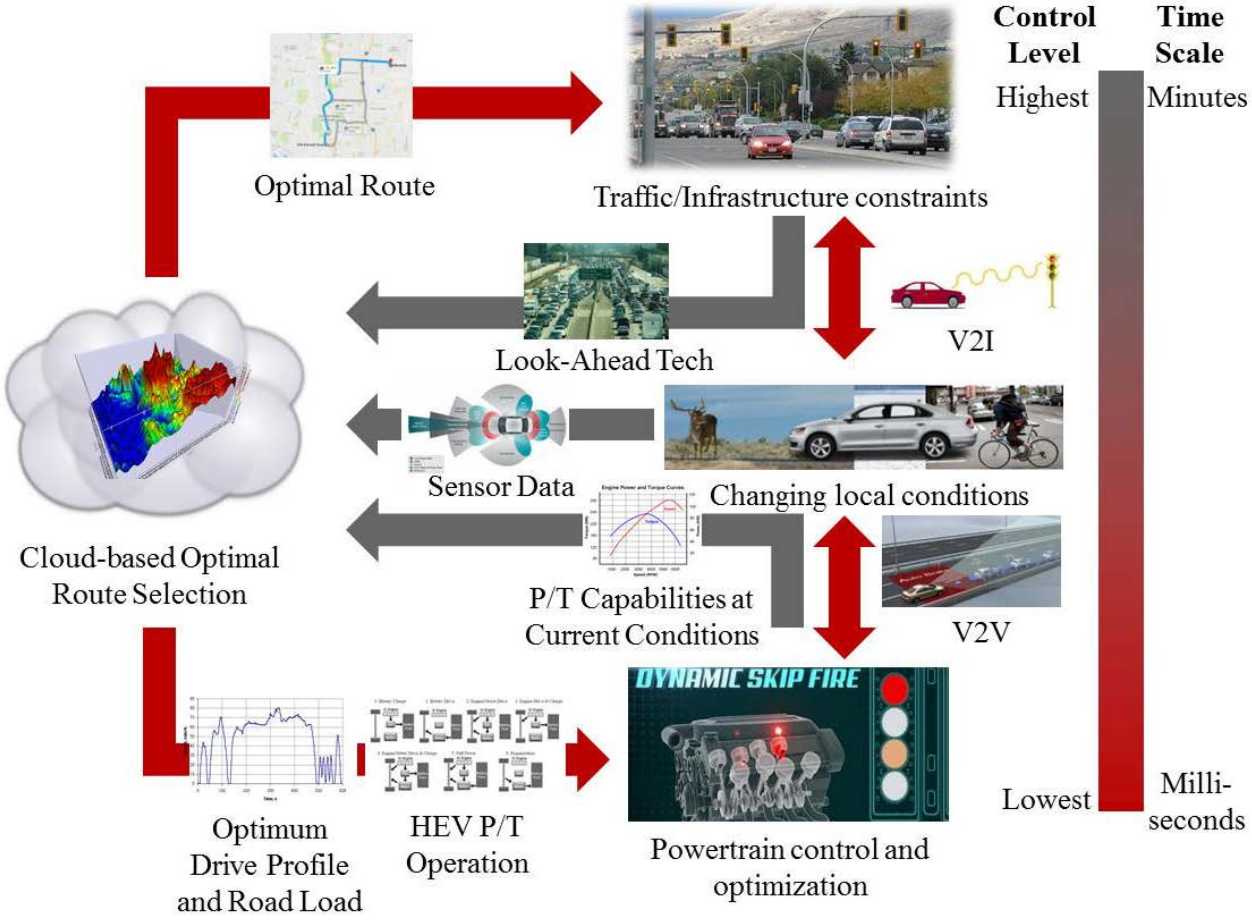
Background:
Independent automotive proving ground that provides R&D and compliance and certification test services

Role:
Support test and development activities to demonstrate 20% fuel economy improvement

PI: Josh Every

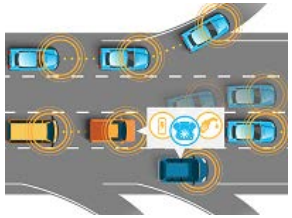


Technology Overview



Objective: Develop an **integrated control system** to improve fuel economy 20% by combining

- CAV and Look-ahead technology
- Mild hybridization
- Advanced cylinder deactivation

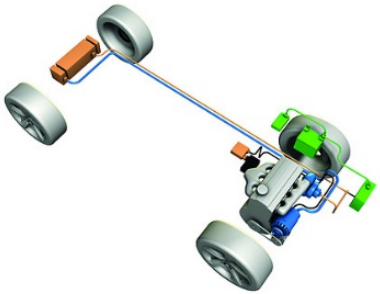


Technology Overview

Advanced Powertrain Technologies

Dynamic Skip Fire (DSF)

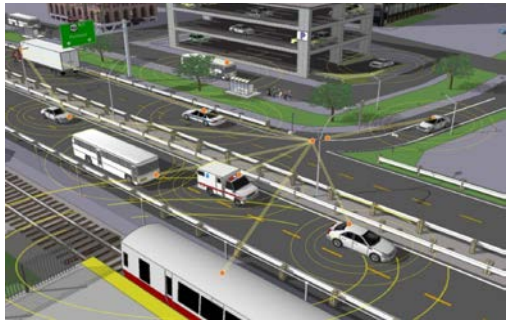
- Advanced valve train technology allowing unique any-cylinder deactivation
- Fuel savings: **6.5%**



48V mild hybridization coupled with DSF

- Typical benefits of E-assist and kinetic energy recovery
- Coupled to DSF to increase the operating zone of DSF via torque smoothing for improved NVH
- Incremental fuel savings: **2.5%**

CAV Technologies

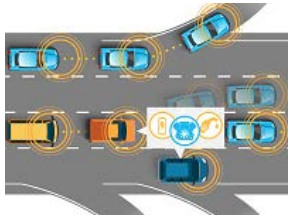


Look-Ahead Technologies

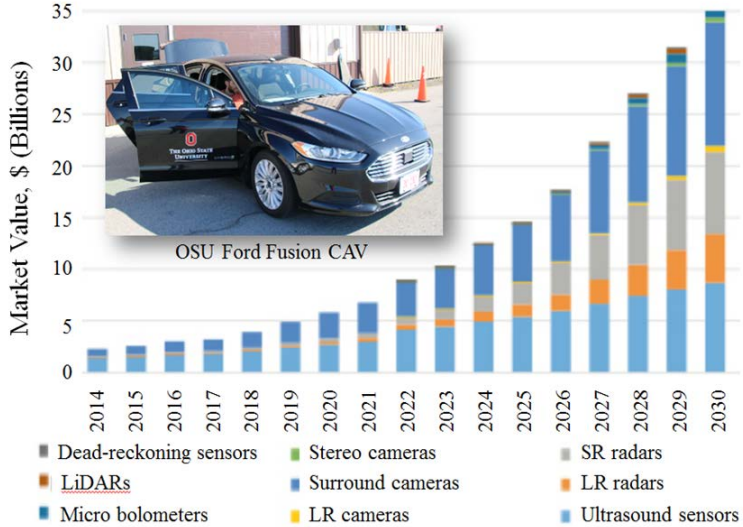
- V2X sensors and radios to provide information about surrounding environment and conditions ahead
- Fuel savings: **7%**

Cloud Computing

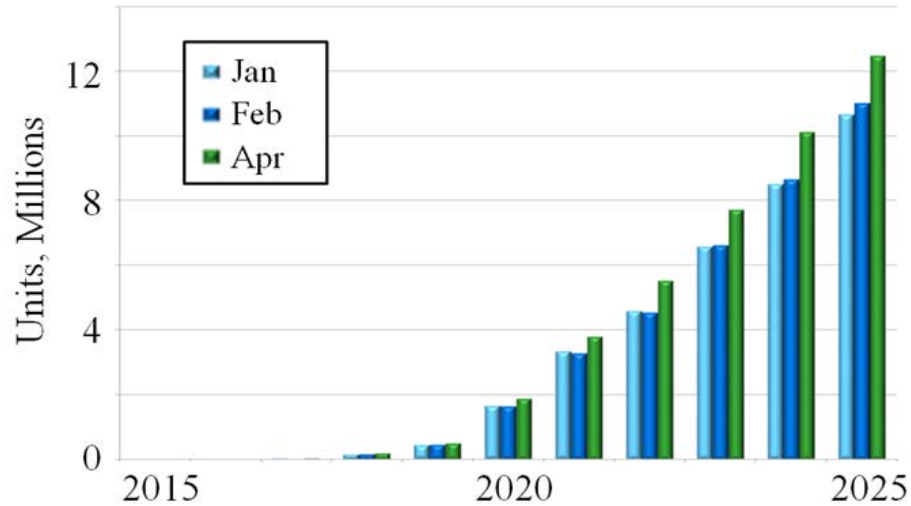
- Synergistically merge CAV tech information with powertrain control to minimize fuel consumption
- Additional Fuel savings: **4%**



Technology-to-Market Approach



Projected Growth of CAV Technology



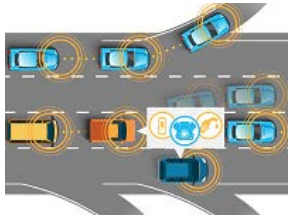
Projected Penetration of Mild Hybrid Technology

Market Impact

- The proposed concept has clear cost/performance advantages over other approaches, especially given that much of the hardware required is expected to be commonplace in 2025
- The CAV technology market is projected to explode over the next decade, enabling seamless integration in future vehicles

T2M Strategy

- Delphi is a top supplier of electronic systems and is well-informed of the needs of its OEM customer base
- Two approaches are planned for technology transition
  - Selling the software function as part of an integrated electronics module provided by Delphi
  - Licensing the software for use on existing OEM modules



Key challenges

Risk #1

- Impact of DSF on small 4 cylinder engine NVH characteristics not well established
- While DSF has demonstrated considerable fuel savings on large engines (V8), fuel savings will be less on smaller 4-cylinder engines due to limitation of operating zone by NVH considerations

Mitigation Strategy

- Implement a mild hybrid system to enable torque smoothing and a wider operating range with acceptable NVH characteristics
- Develop combustion and control models to understand NVH limitations and ensure maximum synergy with the 48V system

Risk #2

- Vast amount of information provided by CAV technologies will present complexity to the control structure
- Addition of drivability and emissions considerations further complicates the control

Mitigation Strategy

- Develop the controls in stages, starting at the highest level of information and working down
- Identify and prioritize the incoming information that will have the largest impact; ignore less critical information