Future Propulsion Systems

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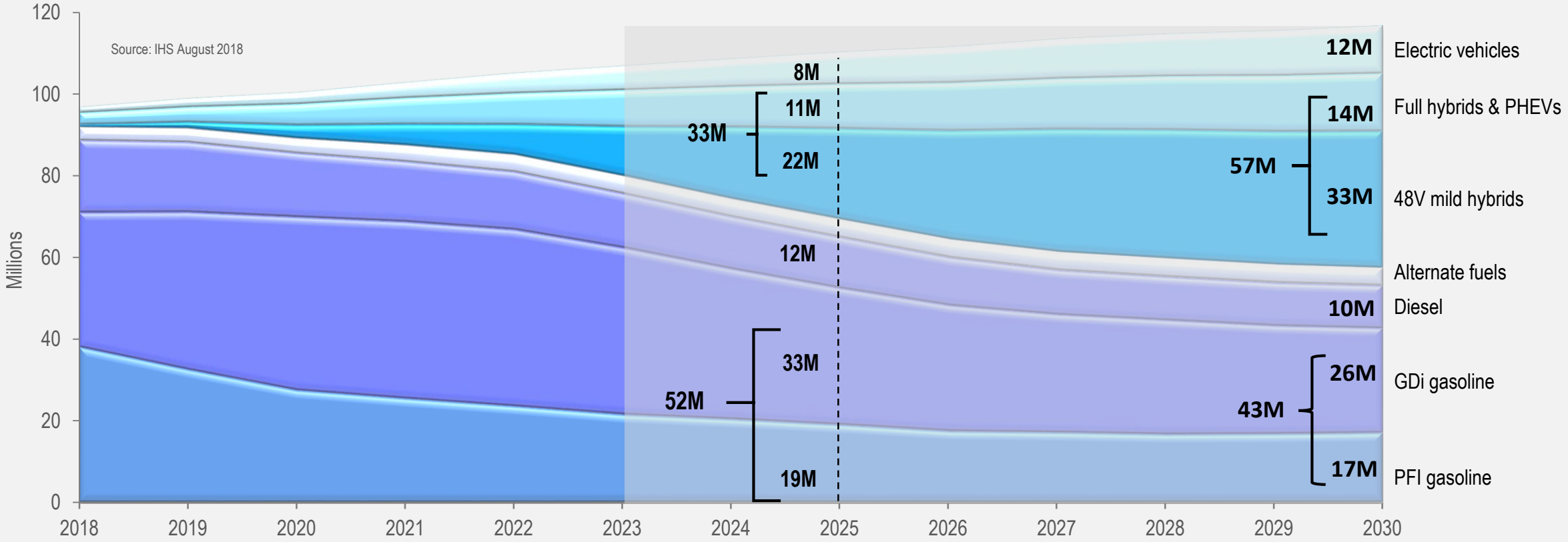
Driven to make a difference

Light-duty hybrids expected to grow

Annual hybrids sold forecasted to increase in the next 10 years: ~32 m by 2025



Electrification mix unclear after 2023 as OEMs adjust to meet stringent regulatory targets

Electrification:
Combining functions to reduce size & cost

Propulsion inverter

+

DC-to-DC Converter

CIDD (Combined Inverter DC/DC)

- Eliminates extra DC cables and separate DC/DC housing
- Eliminates extra liquid cooling lines
- Fewer components to install in vehicle

Design for High Pressure

Multi-hole Injector M16 for 500+ bar Pressures

Multec 16 – 500+ bar

500+ bar customized elastomer interface

Optimized:
- internal fuel routing
- magnetic performance
- materials

Decoupled armature-pintle assembly

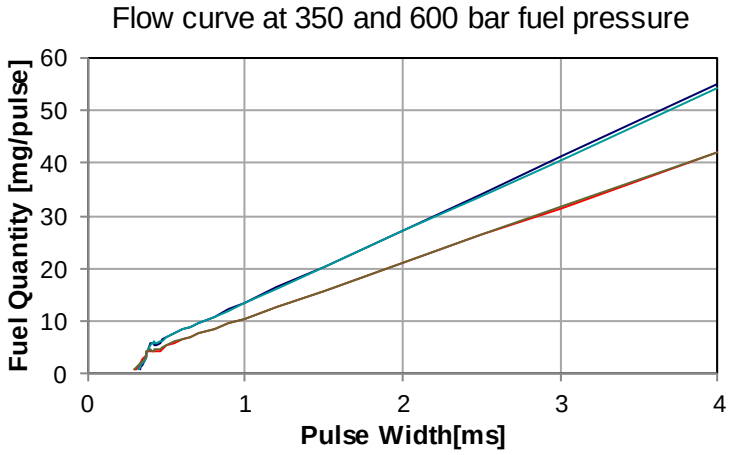
6mm lower housing with machined seat

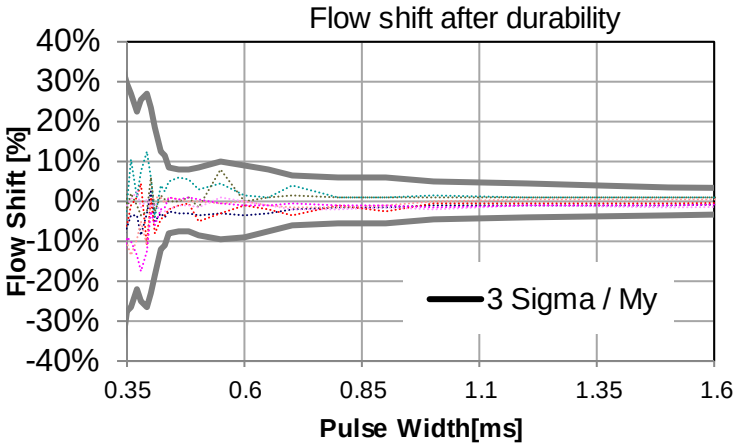
Benefits

- Optimized injector fueling
- Noise reduction
- Drive wave form energy reduction

Status

- Advanced development validation completed





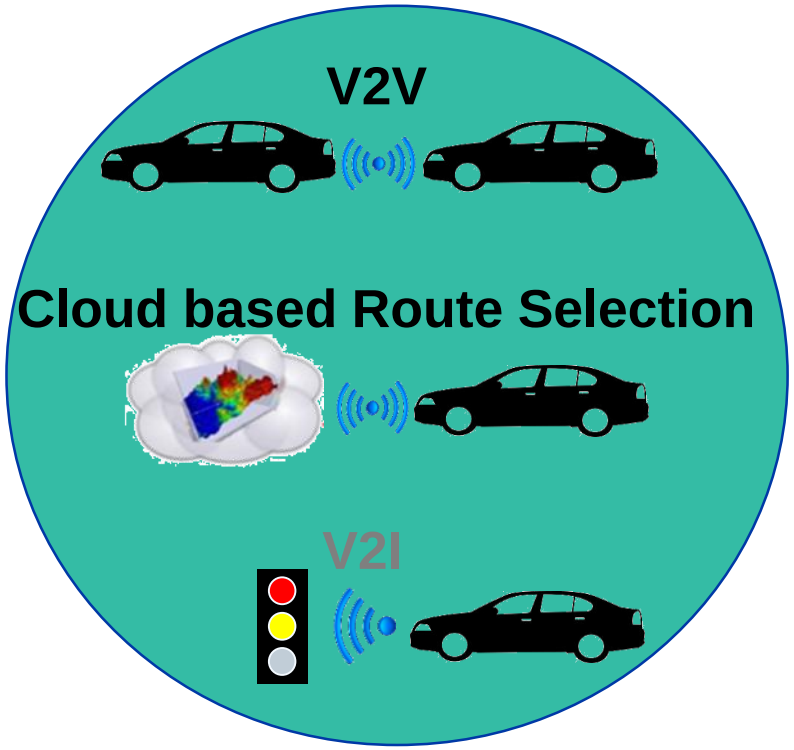
Multec 16 with up to 600 bar system pressure capability

48V eDSF: Demonstrated Benefits

- 15+% CO_2 REDUCTION
- INCREASED LOW-END TORQUE
- 20%+ IMPROVED ACCELERATION (0-30 KPH)
- INCREASED CHARGING DURING DECELERATION
- SEAMLESS START-STOP PERFORMANCE

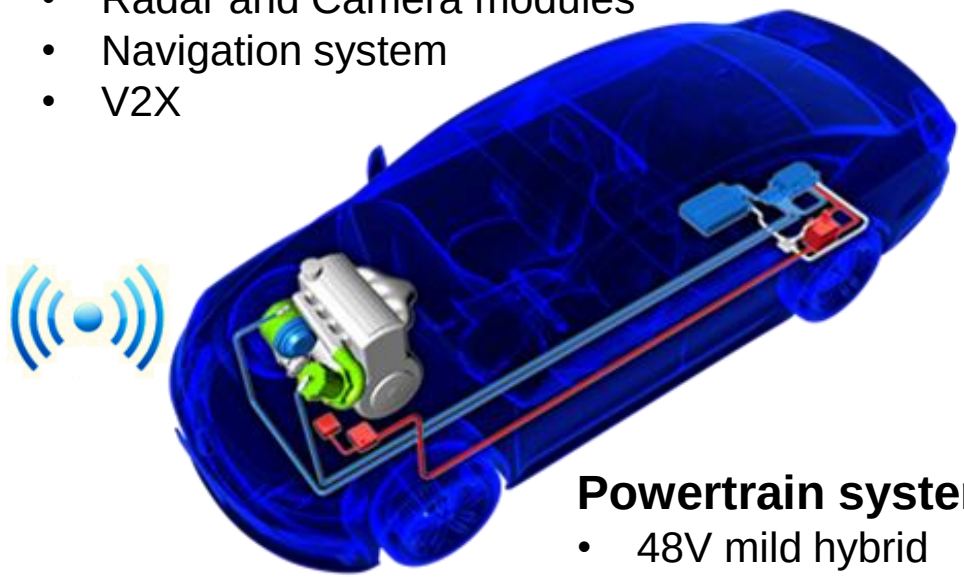
Realizing the system synergies of powertrain technologies and capabilities

ARPA-E NEXTCAR Project
48V eDSF with Intelligent Driving



Connected & ADAS systems

- Radar and Camera modules
- Navigation system
- V2X



Powertrain systems

- 48V mild hybrid
- Dynamic Skip Fire
- Powertrain controls

The Ohio State University
Delphi Technologies
APTIV
TULA
TRC Transportation Research Center Inc.
arpa·e

20%+ fuel economy improvement goal: 48V eDSF with connected data

ARPA-E NEXTCAR Project
48V eDSF with Intelligent Driving: Target Benefits

1%-2% improvement estimated for FTP City test cycle

Connected Technologies:
V2X sensors and ADAS systems: topography, surrounding environment and traffic conditions

› **~7%** Fuel Savings

Cloud Computing: Synergistically merge route information with powertrain control to minimize fuel consumption

› **~4%** Additional Fuel Savings

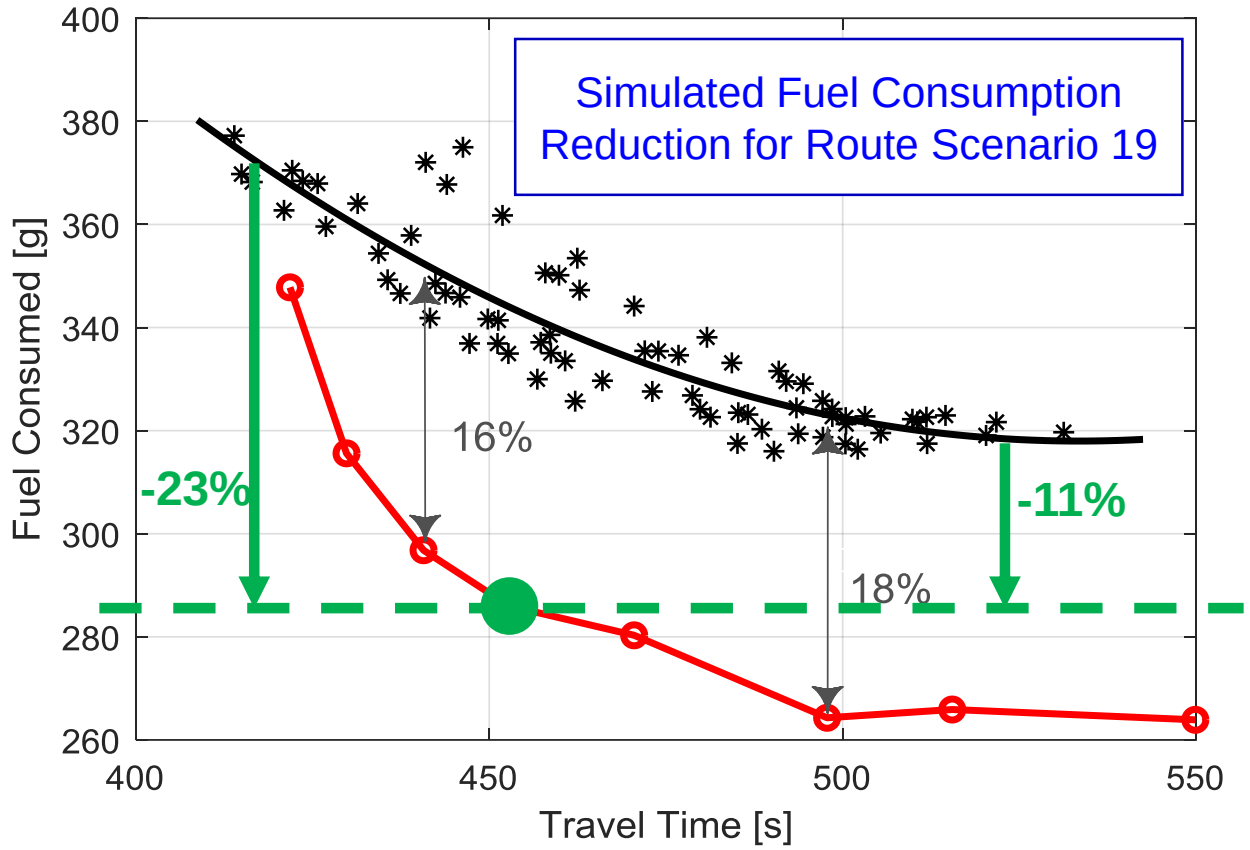
Intelligent driving targeting 10%+ real-world fuel efficiency improvement

NEXTCAR Project: Fuel Economy Evaluation

Simulation results comparing

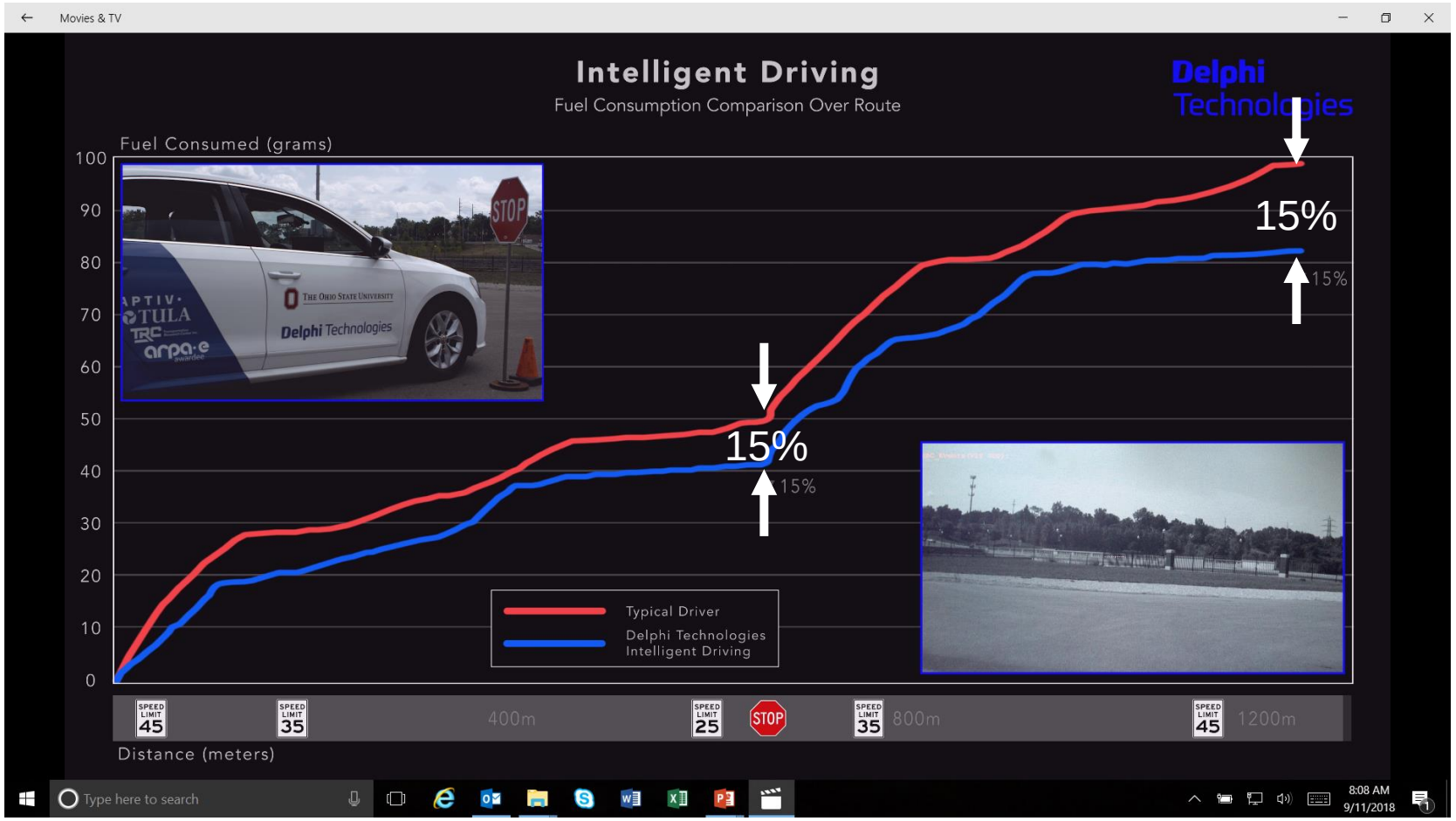
- Driver model
- Intelligent Driving controls

- Driver Model results: represent variation in model parameters.
- Intelligent Driving results: represent variation of aggressiveness parameter between Travel Time and Fuel Consumed.



Simulated Intelligent Driving Controls Demonstrate Significant Potential Benefit

NEXTCAR Project: Fuel Economy Evaluation



Fuel Consumption Evaluation on Test Track with NEXTCAR Development Vehicle

Summary

- Electrification penetration increasing rapidly to complement advanced internal combustion engines
- Connected and Automated Vehicle Systems provide new opportunities for propulsion system optimization
- Software, controls & system integration expertise critical for best value solutions

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