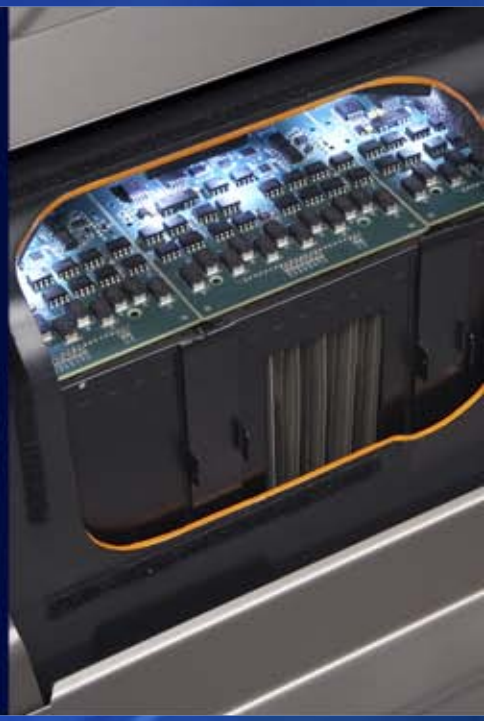
GM
ADVANCED PROPULSION TECHNOLOGY STRATEGY
HYBRID
2 MODE
E85 / Gasoline
Tom Stephens
Vice Chairman, Global Product Operations
General Motors Company

PETROLEUM SUPPLIES…

35%
OF WORLD'S ENERGY

96%
OF TRANSPORTATION ENERGY

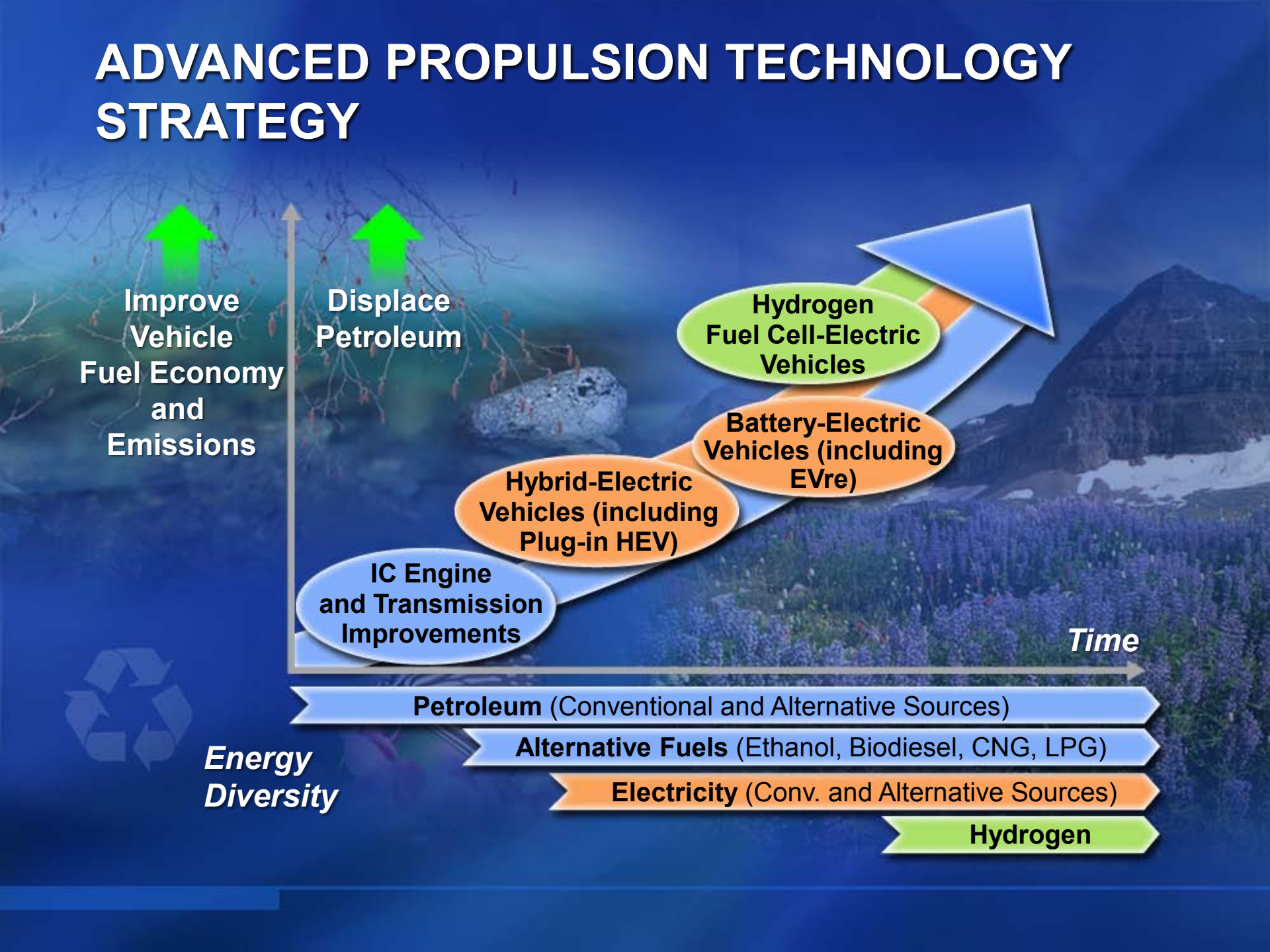
MEGA TRENDS FOR FUTURE POWERTRAINS



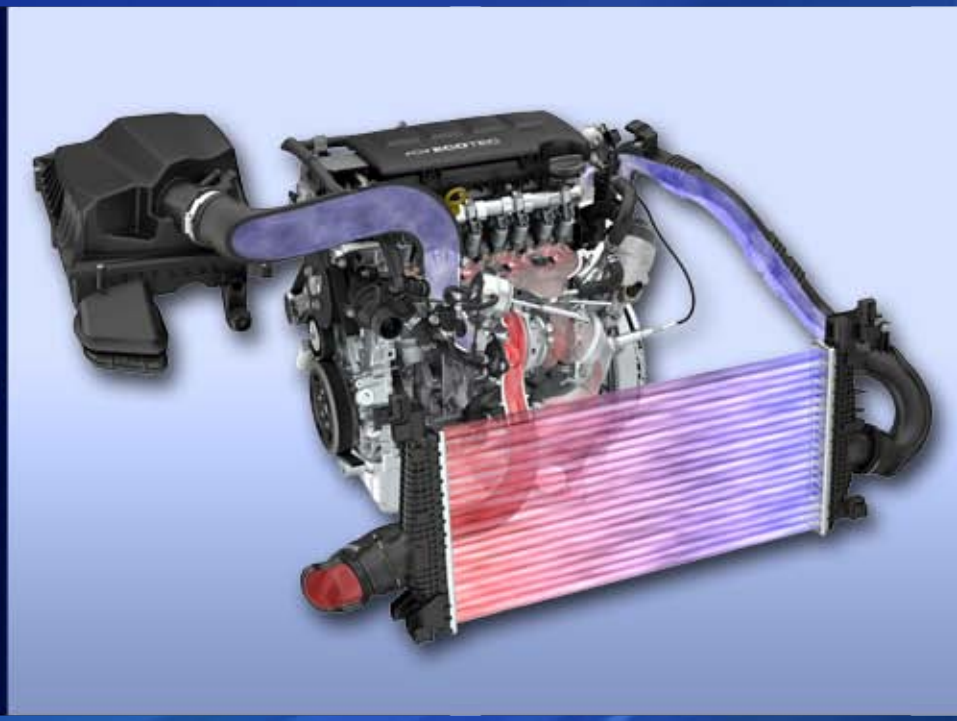
ENERGY DIVERSITY

POWERTRAIN EFFICIENCY

ADVANCED PROPULSION TECHNOLOGY STRATEGY



DOWNSIZED TURBO GAS ENGINE



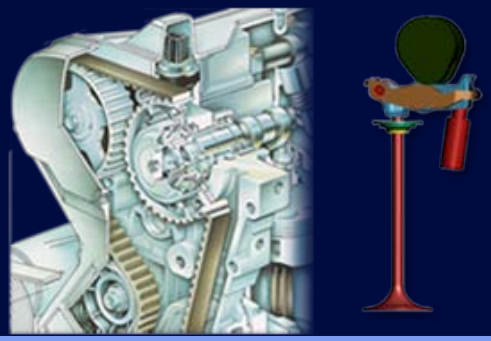
CHEVROLET CRUZE

1.4L TURBO ECOTEC

IMPROVING GASOLINE ENGINES

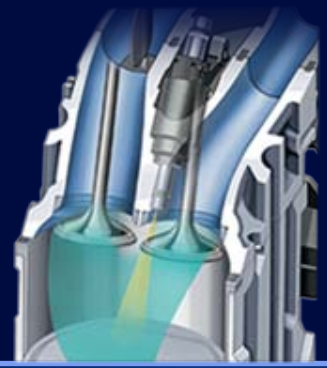
- Modular and Flexible Architectures
- Reduced Mass
- Improved Combustion Technology
- Integration of Leading-edge Technologies

Cam Phasing, Variable Valve Lift, Active Fuel Management



Port Deactivation with EGR

Spark Ignition Direct Injection



Downsized SIDI Turbo Boosting

HCCI – Homogeneous Charge Compression Ignition

CHEVROLET EQUINOX WITH 32 MPG CLASS-LEADING HIGHWAY FUEL ECONOMY

30% Fuel Economy Improvement with Powertrain and Vehicle Enablers

- 2.4L SIDI L4 Ecotec Engine Replaced 3.4L V6

- 6-Speed Automatic with Optimized Shift and Clutch Control

- Rack Electric Power Steering

- Deceleration Fuel Cut-off
- Idle Speed Reduction

- Electronic Returnless Fuel System
- Aerodynamic Drag Reduction
- Regulated Voltage Control
- Optimized Tire Rolling Resistance

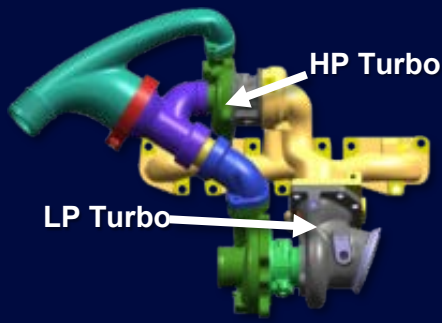
HOMOGENEOUS-CHARGE COMPRESSION-IGNITION (HCCI)

DIESEL ENGINES – ACHIEVING THE LOWEST EMISSIONS

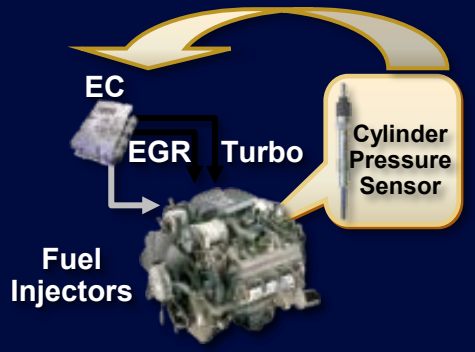
Base Engine Technologies

- High Pressure Injection
- Lower Compression Ratios
- Higher Peak Cylinder Pressure

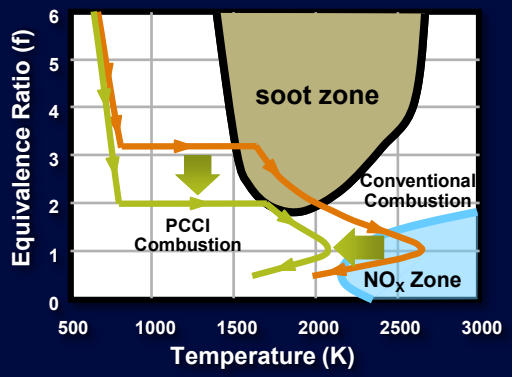
Advanced Boosting with Small Displacement



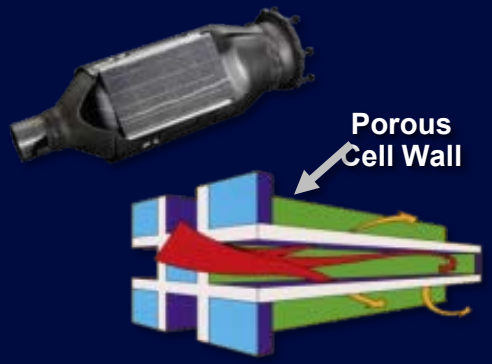
Cylinder Pressure Sensing



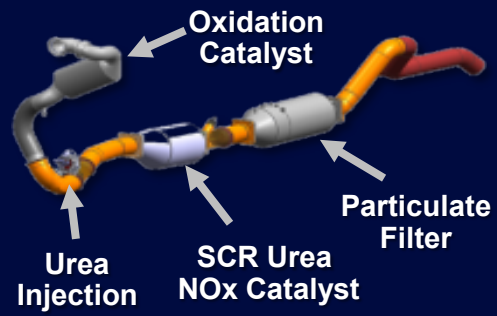
PCCI Combustion



Diesel Particulate Filter



NO_X Aftertreatment

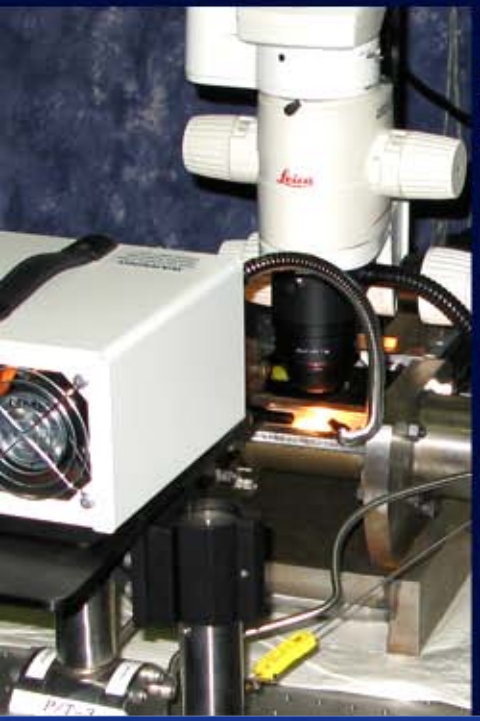


DURAMAX 6.6L TURBO DIESEL

GMC SIERRA

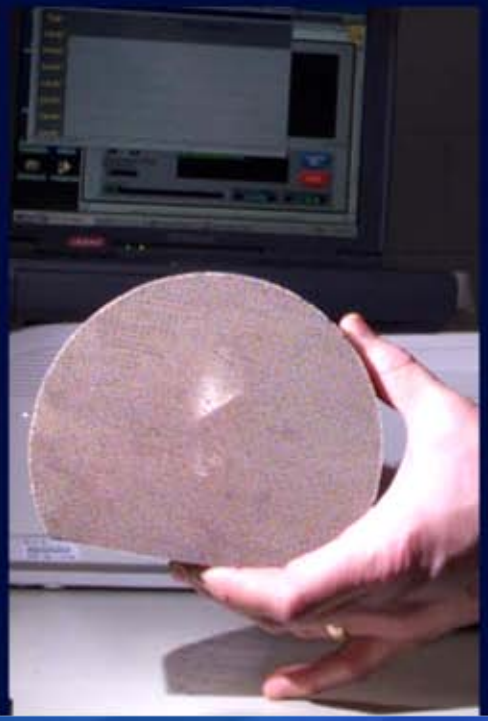
6.6L TURBO V-8

ARGONNE NATIONAL LAB

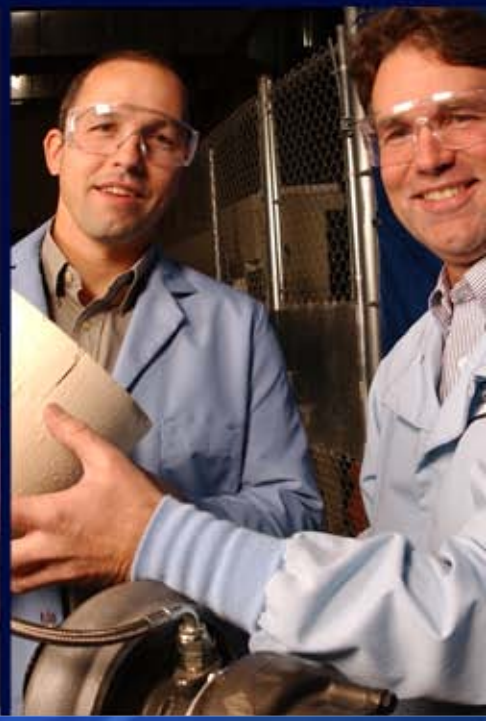


SANDIA NATIONAL LABS

OAK RIDGE NATIONAL LAB



PACIFIC NORTHWEST NATIONAL LAB



GM ETHANOL VEHICLES

OVER 5.5M VEHICLES WORLDWIDE AND 19 MODELS IN NORTH AMERICA

ENERGY DIVERSITY – ETHANOL

coskata

MASCOMA

ENERGY DIVERSITY – CNG AND LPG

ELECTRIFICATION STRATEGY

PORTFOLIO OF SOLUTIONS FOR FULL RANGE OF VEHICLES THAT PROVIDE CUSTOMER CHOICE

Petroleum and Biofuels
(Conventional and Alternative Sources)

Electricity and Hydrogen
(Zero Emissions Energy Sources)

Mild Hybrid	Strong Hybrid	Plug-in Hybrid	Extended-Range Electric	Battery Electric	Fuel Cell Electric

Increasing Electrification

MILD HYBRID SYSTEM

- Up to 20% city fuel economy improvement
- 115 volt, 15kW system
- Midsize vehicles
- North America and Asia

2-MODE RWD HYBRIDS

2-MODE RWD HYBRIDS

- Up to 40% city fuel economy improvement
- City fuel economy equal to 4-cylinder sedan
- Tow up to 6,100 pounds
- Only full hybrid for full-size trucks and SUVs

PLUG-IN 2-MODE FWD HYBRID

- Front-wheel-drive architecture
- Active program under development for production
- Beginning in 2012

KILOWATTHOURS
BlackBerry
Mobile
Updated 11/5/2010 4:27 PM from Sparky
Battery
55 %
EV Range
22 Miles
Total Range
282 Miles
Charge Mode - Grid Friendly
PLUG IN TO CHARGE
VOLT

ELECTRIC VEHICLE WITH RANGE-EXTENDER

25-50 Miles
Battery Electric
Drive

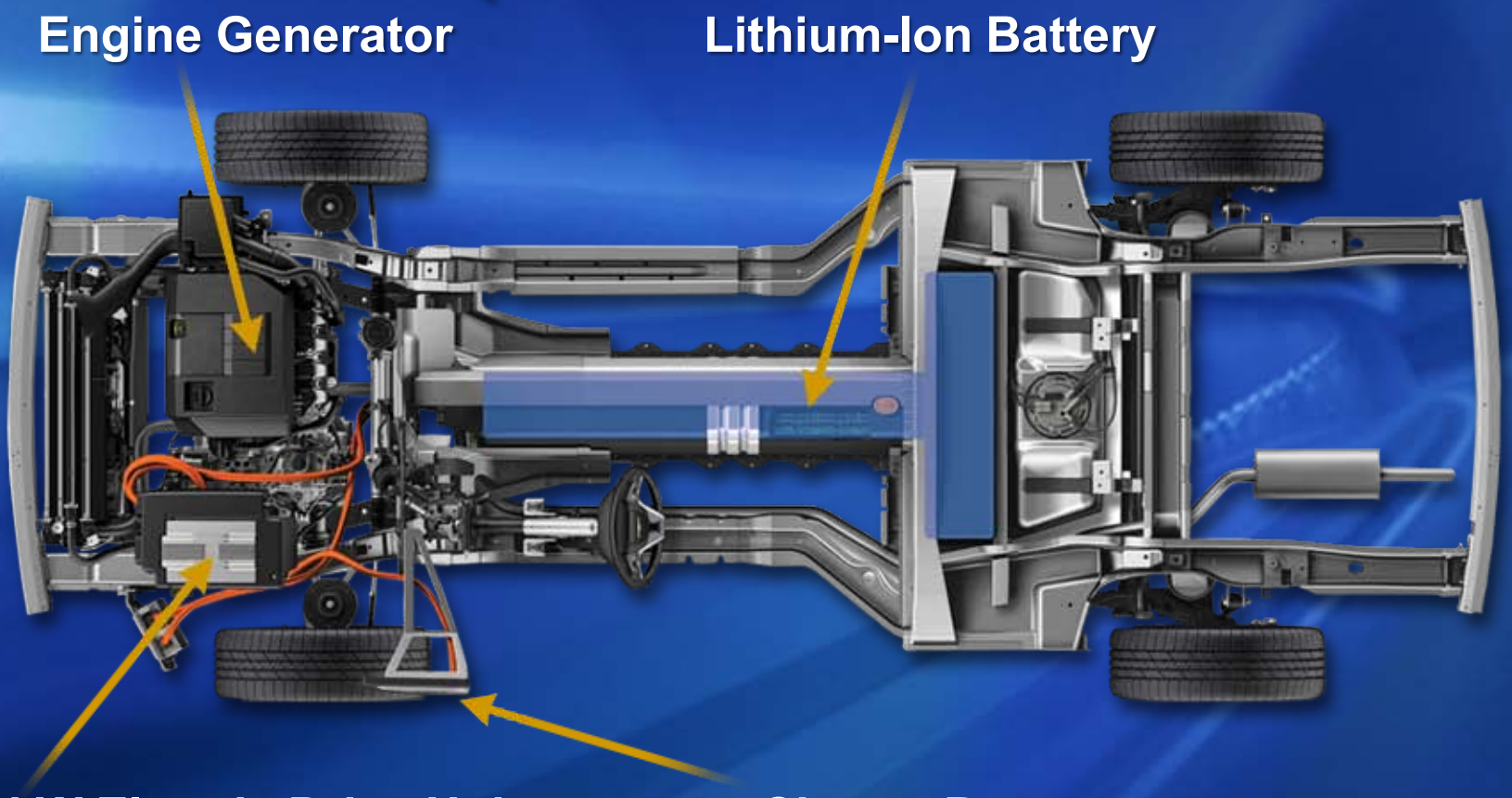
+

Hundreds of
Miles Extended-
Range Driving

LITHIUM-ION BATTERY

- 16-kWh battery pack
- High energy, high power in minimized package
- 8-year/100,000-mile warranty

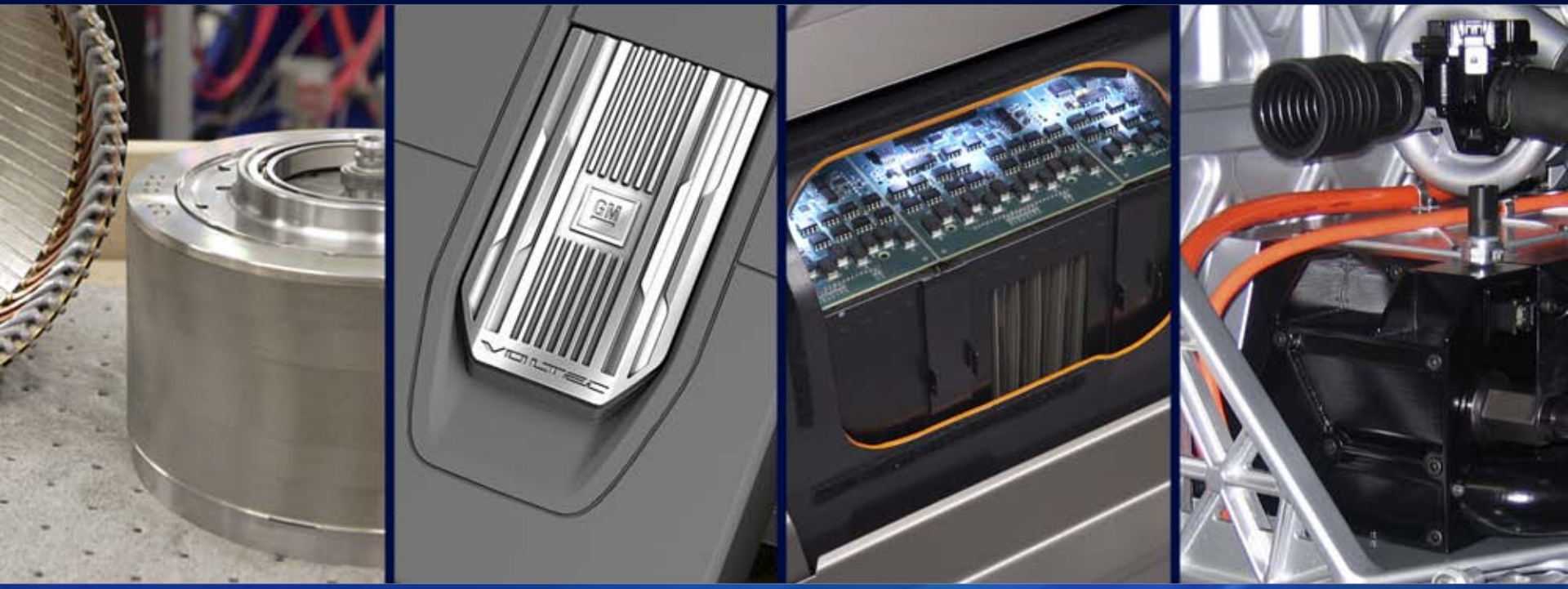
VOLT


Engine Generator
Lithium-Ion Battery
111 kW Electric Drive Unit
Charge Port

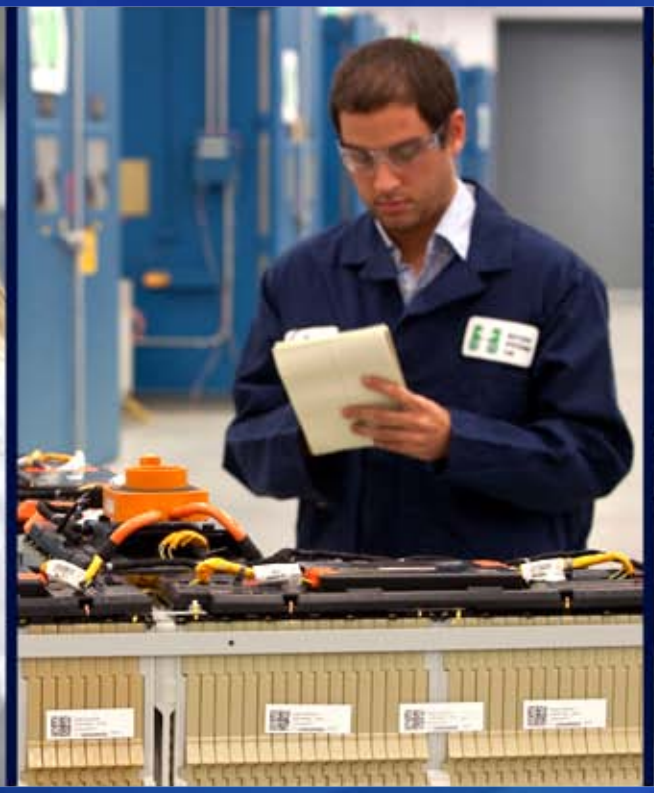
CHARGING AND INFRASTRUCTURE

POWERTRAIN ELECTRIFICATION

ELECTRIC MOTORS POWER CONTROL BATTERIES FUEL CELLS



GLOBAL BATTERY SYSTEMS LAB



BROWNSTOWN TOWNSHIP
BATTERY MANUFACTURING PLANT

PROJECT DRIVEWAY

PRODUCTION-INTENT
FUEL CELL SYSTEM

6,500
EVERYDAY DRIVERS

1,700,000
MILES LOGGED

ENERGY DIVERSITY AND POWERTRAIN EFFICIENCY

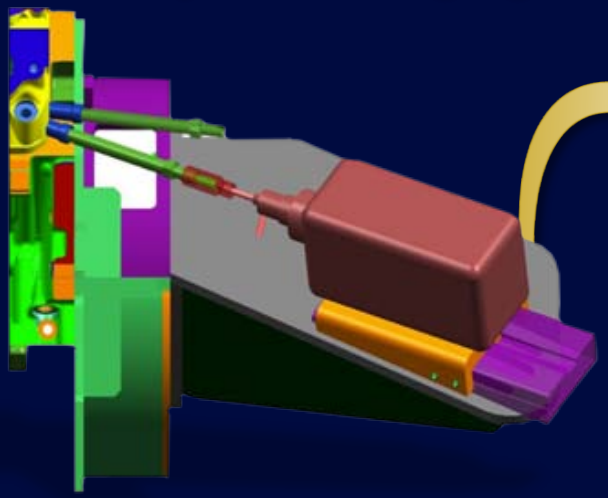
- Future powertrains must be driven by both improved efficiency and energy diversity
- Ethanol is the best near-term option for energy diversity
- CNG and hydrogen will increase in importance over time
- Electrification improves efficiency and offers the potential for energy diversity, while providing a fun-to-drive car with new customer features
- There is no silver bullet … the customer will ultimately choose the technology providing the most value

GM ROAD-LAB-MATH (RLM) STRATEGY

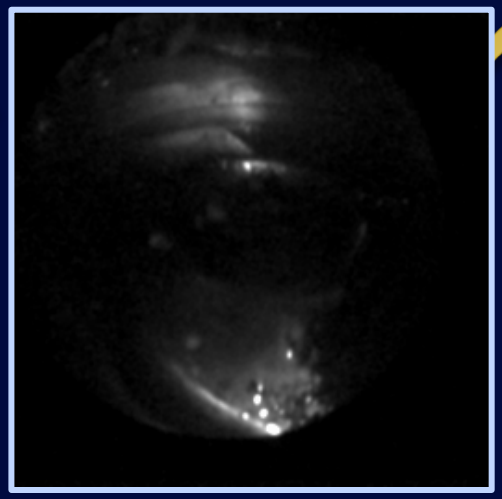
- Fundamental strategy to achieve:
  - Higher-quality design
  - Reduced structural cost
  - Faster product development
- Enable first-time capable designs
- Explore a range of what-if scenarios
- Minimize testing

OPTICAL DIAGNOSTICS AND CFD ANALYSIS

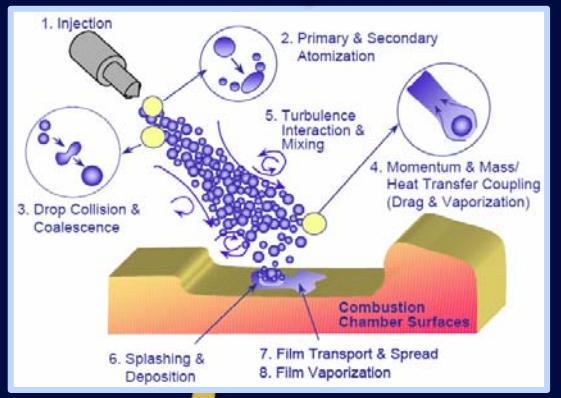
In-Cylinder Imaging



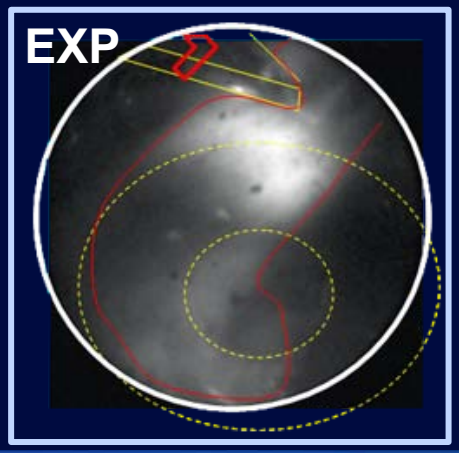
Spray Measurements

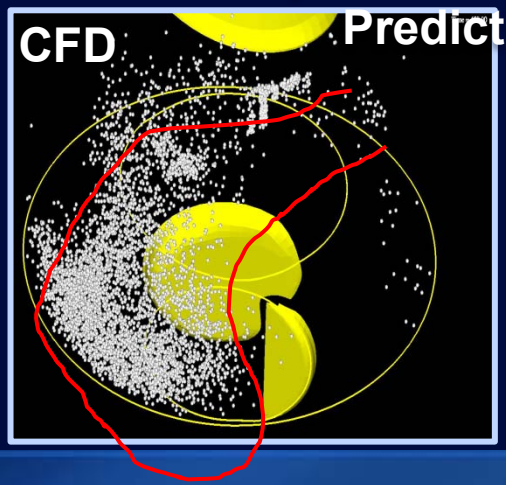


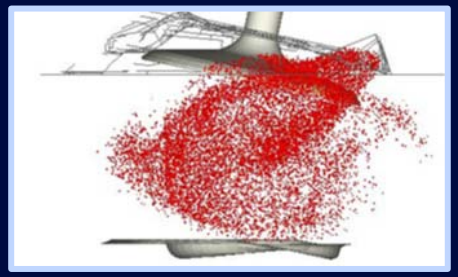
CFD Models Development

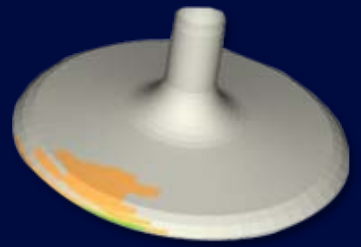


Improved In-Cylinder Predictions



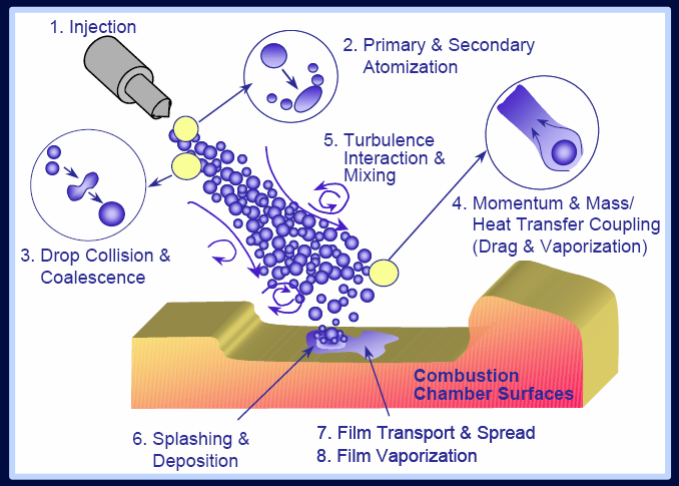


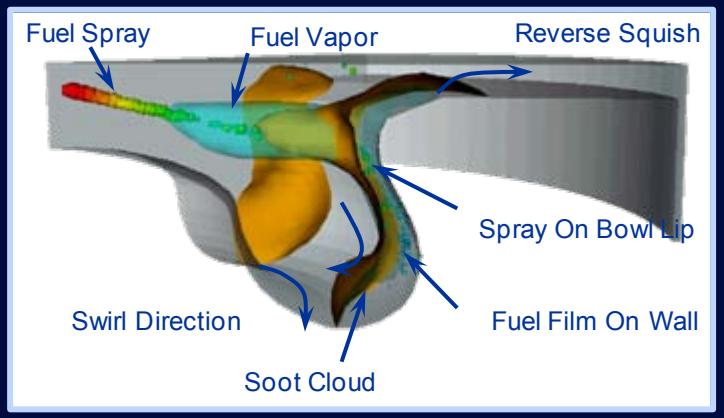


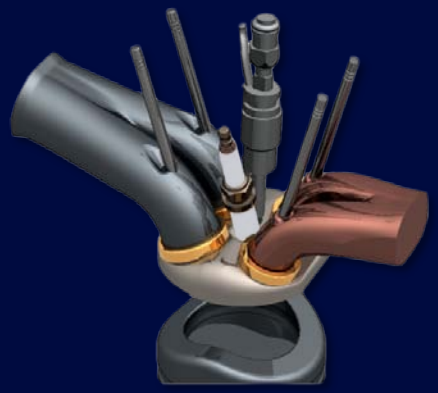


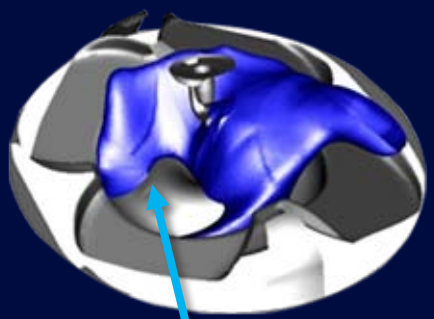
MULTIDIMENSIONAL NUMERICAL SIMULATION

SPRAY, IGNITION, COMBUSTION, AND EMISSION MODELS

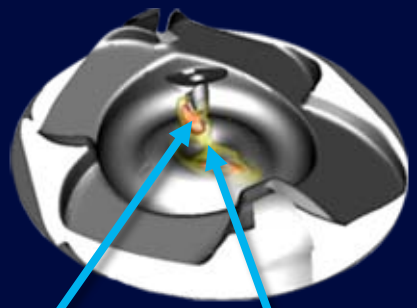






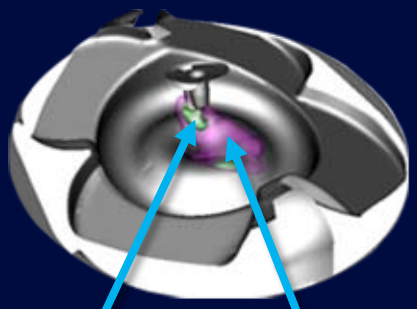


Nitric Oxide



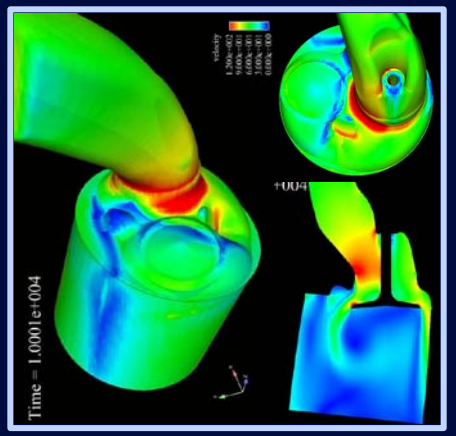
Soot

Soot Number Density



Soot Oxidation

Soot Particle Size Distribution



EASAT: ENGINE & AFTERTREATMENT SYSTEM ANALYSIS TOOLS

PREDICT TAILPIPE EMISSIONS AND FUEL CONSUMPTION

Evaluate Control Strategies

Do Preliminary Calibration

Controller
- Single Variable (PID)
- Multiple Variable (Mod[illegible]ced)

Vehicle
- GT-Drive
- HPSP

Complete Drive Cycle Simulation

Optimize System Design (Engine & AT)

Engine/AT System Architecture

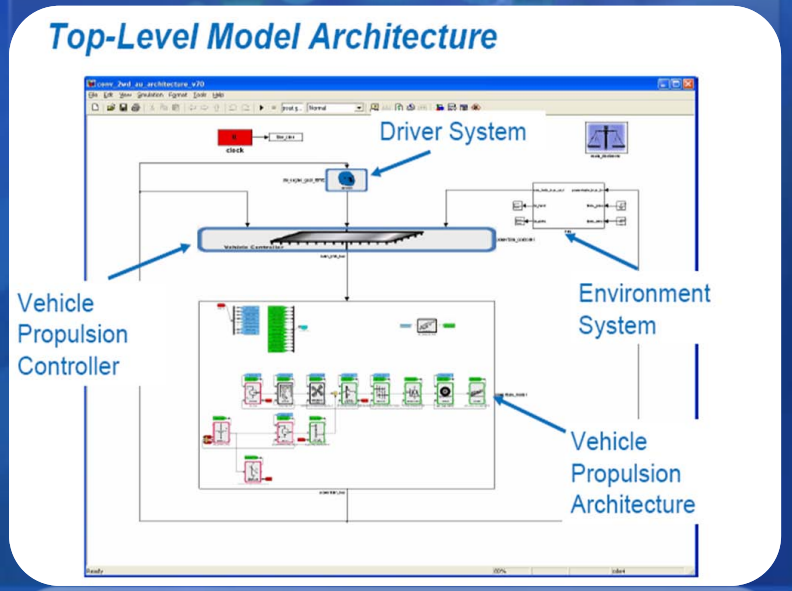
Engine
- GT-Power
- WAVE

Aftertreatment
- 3WC
- DOC
- LNT
- DPF
- SCR

CO, HC, NOx, PM

AUTONOMIE

- Powertrain Model Architecture CRADA
- Argonne National Lab and General Motors
- Plug-and-play environment and architecture supports powertrain control systems design, analysis, and development
- Currently being rolled out as the production tool for GM controls algorithms development



WHAT IS THE FUTURE?

High-speed computing grid needed for:

- Large (CFD) system simulation
- High-fidelity models
- Predictive combustion engine data before actual hardware is available
- Multi-controller simulation
- Optimization studies, limited by current computing throughput

EXTERNAL COLLABORATIONS

- National Labs
  - Sandia – Combustion research
  - Oak Ridge – Diesel particulate filter and ethanol degradation CRADAs
  - Pacific Northwest – Urea SCR CRADA
  - Argonne – Plug-and-play model architecture
  - DOE initiative on predictive numerical simulation
- University network
  - Collaborative Research Labs: U. Michigan, U. Wisconsin
  - Shanghai Jiao Tong U., Tech. U. Darmstadt, Penn State

GM
GMC