NEXTCAR — Next Generation Energy Technologies for Connected and Automated On-Road Vehicles

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Program Director
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Introductions – ARPA-E

- Chris Atkinson, Program Director
- Gokul Vishwanathan, Tech. SETA
- Reid (Rusty) Heffner, Tech. SETA
- Shawn Kimmel, Tech. SETA
- Whitney White, Program SETA
- Dr. Chris Fall, Director of ARPA-E
- Ryan Umstattd, Deputy Director of Commercialization
- John Jennings, Defense Liaison
- Grigorii Soloveichik, Program Director
- Fadl Saadi, Fellow
- Devin Pearson, Meeting Coordinator
Mission
The ARPA-E NEXTCAR Program will fund the development of new and emerging vehicle dynamic and powertrain control technologies (VD&PT) that reduce the energy consumption of future Light-Duty (LD), Medium-Duty (MD) and Heavy-Duty (HD) on-road vehicles through the use of connectivity and vehicle automation.

Goals
- **Energy Consumption:** 20% reduction over a 2016 or 2017 baseline vehicle.
- **Emissions:** No degradation relative to baseline vehicle.
- **Utility:** Must meet current Federal vehicle safety, regulatory and customer performance requirements.
- **Customer Acceptability:** Technology should be transparent to the driver.
- **Incremental System Cost:** $1,000 for LD vehicle, $2,000 for MD vehicle and $3,000 for HD vehicle.

Potential Impact
- **Energy Consumption Reduction:** 4.4 quads/year
- **CO₂ Emissions:** 0.3 GT/year

Program Director
Dr. Chris Atkinson

Total Investment
$35 Million over 3 years
ARPA-E’s NEXTCAR Vision

Improving the energy efficiency of our future vehicles through research, development and commercialization

‣ What if a vehicle had **perfect information** about
  – Its route and topography
  – Environmental conditions
  – Traffic conditions
  – Traffic behavior
  – Condition of its powertrain and after treatment systems (if any)
  – The quality of its fuel (if used)
  – ……and everything else

‣ And it **cooperates** with all the vehicles around it in order to reduce its energy consumption,

‣ With **perfect control** and optimization?

ARPA-E strives for towards commercialization of the technologies that it supports – without commercial applications, we will not see the energy efficiency improvements that we seek.
Future Powertrain and Vehicle Control with NEXTCAR

- V2x Cellular WiFi Satellite (Route, Weather, Traffic)
- V2V, DSRC (Immediate Vehicle Ahead Information)
- Short Range Machine Vision (Camera, Radar, Lidar)

Human Visual Input (Road Conditions Traffic Conditions)

Dynamic Instantaneous Vehicle Feedback/Sensation

Accelerator Brake Gear Inputs

Powertrain Feedback

Powertrain Controller

Desired Output
Vehicle Speed Acceleration Fuel/Energy Consumption Emissions

Longitudinal Vehicle Feedback (6 Axis)

Traction Control/Stability Control

V2x Cellular WiFi Satellite (Route, Weather, Traffic)

V2V, DSRC (Immediate Vehicle Ahead Information)

Short Range Machine Vision (Camera, Radar, Lidar)
NEXTCAR Projects – 2017-2020

- General Motors - InfoRich VD&PT Controls (*Carnegie Mellon U, NREL*)
- Michigan Technological University - Hybrid Electric Vehicle Platooning Control (*GM*)
- Ohio State University - Engine Cylinder Optimization in Connected Vehicles (*Delphi, Tula Technologies*)
- Pennsylvania State University - Fuel Efficiency through Co-Optimization (*Volvo Trucks*)
- Purdue University - Connected and Automated Class 8 Trucks (*Cummins, Peterbilt*)
- Southwest Research Institute (SwRI) - Vehicle Model Predictive Control (*Toyota, UM*)
- University of California, Berkeley - Predictive Data-Driven Automotive Control (*Hyundai of America*)
- University of California, Riverside - Efficient Plug-In Hybrid Electric Buses (*US Hybrid*)
- University of Delaware - Optimized Vehicles through Connectivity (*Bosch, BU*)
- University of Michigan - Integrated Vehicle Power & Thermal Management (*PNNL*)
- University of Minnesota - Optimized Delivery Vehicles (*Workhorse*)
# NEXTCAR Awardee Distribution

<table>
<thead>
<tr>
<th></th>
<th>ICVs</th>
<th>HEVs</th>
<th>PHEVs</th>
<th>Other</th>
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</thead>
</table>
| LD    | • General Motors | • Ohio State University | • University of Delaware  
• Michigan Tech. University  
• University of California – Berkeley  
• Southwest Research Institute | • University of Michigan |
| MD    |               | • University of Minnesota | • University of California Riverside |                                      |
| HD    | • Penn State University  
• Purdue University |               |                                                        |                                      |

**Colors**
- **Green** - Gasoline  
- **Blue** - Diesel  
- **Yellow** - Natural Gas
NEXTCAR Timeline and Critical Milestones

Approximate Program Timeline

- 2016: Program Development
- 2017: Program Kickoff
- 2018: Year-1
  - Vehicle acquired and connectivity feature implemented
- 2019: Year-2
  - Intermediate energy consumption improvement demonstration
- 2020: Year-3
  - Final demonstration to meet program goals (~20% energy consumption improvement)
The Building Blocks of Autonomy

Source: Vision Systems Intelligence
Navigant Research Leaderboard: Automated Driving Vehicles

Several of these leaders are in the NEXTCAR Program Portfolio

Source: Navigant
NEXTCAR Participants

- Automakers – number 2, 4 and 5 worldwide by sales
- Largest independent engine manufacturer by revenue
- Largest automotive supplier worldwide by revenue
- Truck manufacturers – number 2 and 3 worldwide by sales revenue
Annual Review Meeting Objectives

What are we here for –

‣ To formally report on the end of Year 1 of NEXTCAR,
‣ To hear about the technical & commercialization progress of each of the Projects,
‣ Including lessons learned, solutions to common problems, and to discuss common challenges,
‣ To hear from industry, government and policy leaders about the state of the art and future directions in this area, and
‣ To continue the creation of an R&D and commercialization ecosystem around the improvements in energy efficiency of CAVs,
‣ Re-introduce ourselves to each other, get to know what others are doing, get to know the state of the art, to report on achievements, and to get a sense of the challenges and the possibilities ahead of us,
‣ Your competition is not across your table but is the State-of-the-Art – Exchange of knowledge between teams is highly recommended
Instructions for this Annual Review

- Tell us about
  - Your project successes,
  - Your lessons learned,
  - Remaining challenges,
  - Best practices,
  - Useful SW, hardware, methods and techniques

- Network and exchange ideas

- Conferences, workshops, opportunities?
## Requirements for Commercial Success

Any new powertrain technology should be comparable to or better than the baseline in:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Explanation</th>
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<tbody>
<tr>
<td><strong>Power</strong></td>
<td>Power density (or energy density including the fuel/energy storage capacity) ⇒ Customer acceptance</td>
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<tr>
<td><strong>Efficiency</strong></td>
<td>Fuel economy (over real-world dynamic driving) ⇒ Regulation</td>
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<tr>
<td></td>
<td>Energy efficiency</td>
</tr>
<tr>
<td><strong>Emissions</strong></td>
<td>Regulated criteria pollutants (and CO$_2$) ⇒ Regulation</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Total cost of ownership (including capex and energy cost)</td>
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<tr>
<td><strong>Reliability</strong></td>
<td>Mean time between failures, maintainability</td>
</tr>
<tr>
<td><strong>Utility</strong></td>
<td>Acceleration, driveability, NVH, cold or off-cycle operation, ease of use, transparency to the user, refueling, and acceptable range</td>
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<tr>
<td><strong>Fuel acceptability</strong></td>
<td>Use a readily available fuel or energy source.</td>
</tr>
<tr>
<td><strong>SAFETY</strong></td>
<td>Non-negotiable.</td>
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How hard can it be to develop an autonomous vehicle?

Quite tough, actually.
Testing, Validation and Verification

• Safety!
• No on-road testing (unless the road is closed to other traffic)
SAE WCX 2018 – Significant thrust in NEXTCAR type technologies

- Panel: Validation is the path to getting on the road for automated vehicles – What is it going to take to get us there?
- Drive scenario generation based on metrics for evaluating an Autonomous Vehicle Speed Controller for Fuel Efficiency Improvement – 2018-01-0034 (OSU)
- Towards Improving Vehicle Fuel Economy with ADAS – 2018-01-0593 (CSU)
- Utilization of ADAS for Improving Performance of Coasting In Neutral – 2018-01-0603 (Hyundai-Kia and OSU)
- Fuel Efficient Speed Optimization for Real-World Highway Cruising - 2018-01-0589 (ANL)
- Exploring Telematics Big Data for Truck Platooning Opportunities – 2018-01-1083 (NREL, Montana State University and Volvo Group)
SAE WCX 2018 – Significant thrust in NEXTCAR type technologies

- Influences on Energy Savings of Heavy Trucks Using Cooperative Adaptive Cruise Control – 2018-01-1181 (NRC, NREL, UCB and Volvo)
- Predictive Energy Optimization for Connected and Automated HEVs - 2018-01-1179 (Jaguar Land Rover)
- Electric Vehicle Performance Enhancement over Eco-Driving Cycles Employing CAV Technologies (ORNL and UCR – Oral only)
- Energy Efficiency of Autonomous Car Powertrain – 2018-01-1092 (University of Cambridge and Mahle Powertrain)
- Various V2I and DSRC discussions
- ....
NEXTCAR R&D Ecosystem Development Activities

• Field Day in 2019/2020?

• Focused session in SAE WCX on energy efficiency improvements in CAVs (2019?)

• Other opportunities
Agenda Snapshot

Day-1

- Current state and Future CAV Trends – Roger Berg (Denso)
- Light-duty vehicle team presentations
- Panel: Advances in Enabling Technologies for NEXTCAR (Pravin Varaiya (UCB), Roy Goudy (CAMP) and Rajeev Thakur (Osram))
- Autonomie/Polaris tutorial and discussion – Aymeric Rousseau (ANL)
- **Poster Session and Networking**

Day-2

- Medium and heavy-duty vehicle team presentations
- DOE VTO EEMS Perspectives – David Anderson (VTO)
- ARPA-E T2M – Ryan Umstattd (ARPA-E)
- Commercial vehicle connectivity – Sandeep Kar (Fleet Complete)
- Tier-1 Supplier perspectives – Ben Saltsman (Magna)
- Panel: Driving Adoption of NEXTCAR Technology in Light-Duty Vehicles (Aaron Hula (EPA), John German (ICCT) and Tim Johnson (Corning))
Questions?

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