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

2020 Annual Program Review
May 12, 2020
This webinar can support up to **1000 participants**. If for some reason we experience latency issues, we will hold the meeting with critical team members only (and NOT more than 5 critical people per team).

**Only the presenter MUST turn ON their video.** The remaining attendees MUST NOT turn on their video feature. At the beginning of the meeting, no one except Chris will turn ON their videos.

We will be driving the slides from Gokul Vishwanathan’s computer. We will **NOT pass the presenter** privileges to any presenter. Please do NOT attempt to steal or request presenter privilege.

Everyone except the presenter **MUST be on mute**. Those passively participating in the meeting (i.e. everyone except the PIs, presenters and ARPA-E team) MUST NOT turn on their microphones.

Questions **CANNOT be asked verbally** during or after the presentation since everyone will be on mute. Please use the CHAT feature to post your questions to **Reid Heffner only** using the private chat feature (and NOT to the entire audience) either during the presentation or after the presentation. Reid (Rusty) will act as the moderator for filtering pertinent questions. Q&A session and discussion will be held after all the project presentations.

**Presenters, PLEASE present your slides in the allotted time limit of 7 minutes.**
Agenda

‣ Opening Remarks & Introduction – Chris Atkinson
‣ NEXTCAR Team Presentations
  – Michigan Tech. – Jeff Naber
  – GM – Chen-Fang Chang
  – SwRI – Scott Hotz or Sankar Rengarajan
  – OSU – Giorgio Rizzoni
  – UCB – Francesco Borrelli
  – University of Delaware – Andreas Malikopoulos
  – University of Michigan – Jing Sun
  – University of Minnesota – Will Northrop
  – UCR – Matt Barth
  – PSU – Sean Brennan
‣ Q&A and Discussion
‣ Concluding Remarks – Chris Atkinson and Mary Yamada
ARPA-E and NEXTCAR Current Status

- ARPA-E – under full telework (since March)
- NEXTCAR teams
  - None currently have access to their vehicles
  - Plans for restarting? Yes, many plans…
- No Cost Extensions – until 12/31/2020 in many cases
- Budget adjustments – no information as yet
- Program Director transition – Marina Sofos, PhD.
ARPA-E NEXTCAR Team

Chris Atkinson
Program Director

Marina Sofos
Program Director

Mary Yamada
Tech-to-Market Advisor

Technical Support
Reid (Rusty) Heffner
Huthaifa Ashqar
Gokul Vishwanathan

Programmatic Support
Whitney White
Ahmed Skaljic
Marina Sofos, Program Director

- Almost 10 years with DOE managing R&D programs in energy efficiency technologies @ Advanced Manufacturing Office & Building Technologies Office

- Interests include sensors, controls & data analytics for energy efficiency

- Degrees in Materials Science & Engineering (Sc.B. Brown Univ, Ph.D. Northwestern Univ, Postdoc Argonne National Lab)
ARPA-E’s Mission

**Mission:** To overcome long-term and high-risk technological barriers in the development of energy technologies

Ensure U.S. Technological Lead & U.S. Economic and Energy Security

- REDUCE IMPORTS
- IMPROVE EFFICIENCY
- REDUCE EMISSIONS
Why is NEXTCAR important to ARPA-E?

21% net efficiency

Source: LLNL, March, 2020. Data is based on DOE/EIA MER (2019). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in ETV-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 45% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE’s analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-TR-110557

CHANGING WHAT’S POSSIBLE
Transportation Energy Usage

Share of total U.S. energy used for transportation, 2018

- Transportation: 28%
- Other: 72%

U.S. transportation energy sources/fuels, 2018

- Gasoline (petroleum): 54%
- Distillates (petroleum): 23%
- Jet fuel (petroleum): 12%
- Natural gas: 3%
- Biofuels: 5%
- Other: 3%

Source: U.S. Energy Information Administration, Monthly Energy Review, Table 2.1, April 2019, preliminary data

Note: Sum of individual components may not equal 100% because of independent rounding.

Source: U.S. Energy Information Administration, Monthly Energy Review, Tables 2.5, 3.8c, and 10.2b, April 2019, preliminary data
Facilitating energy-efficient L1-L3 CAV operation through connectivity and automation.

Using eco-routing, eco-driving, ecoAND, hybrid energy flow optimization, platooning and other connected and L1-L3 automation techniques to improve vehicle energy efficiency by 20%.
Future Powertrain and Vehicle Dynamic Control with NEXTCAR

- Human Visual Input (Road Conditions, Traffic Conditions)
- Dynamic Instantaneous Vehicle Feedback/Sensation
- Accelerator, Brake Gear Inputs
- Powertrain Feedback
- Desired Output: Vehicle Speed, Acceleration, Fuel/Energy Consumption, Emissions

Flow Chart:
1. V2x Cellular WiFi Satellite (Route, Weather, Traffic)
   - V2V, DSRC (Immediate Vehicle Ahead Information)
   - Short Range Machine Vision (Camera, Radar, Lidar)
2. Human Driver
3. Vehicle Controller
4. Powertrain Controller
5. Automated Vehicle Controller
6. Longitudinal Vehicle Feedback (6 Axis)
7. Traction Control/ Stability Control
8. Desired Output

ca. 2016
**NEXTCAR Portfolio**

**Light Duty Vehicles**

- **Gasoline**
  - **GM**
  - **Michigan Tech**
    - Connected and Automated Control for Vehicle Dynamics and Powertrain Operation on a Light-Duty Multi-Mode Hybrid Electric Vehicle
  - **SwRI**
    - Model Predictive Control for Energy-Efficient Maneuvering of Connected Autonomous Vehicles
  - **UC Riverside**
    - Connected Eco-Bus: An Innovative Vehicle-Powertrain Eco-Operation System for Efficient Plug-in Hybrid Electric Bus

- **Natural Gas**
  - **University of Minnesota**
    - Cloud Connected Delivery Vehicle

**Medium Duty Vehicles**

- **Gasoline**
  - **The Ohio State University**
    - Fuel Economy Optimization with Dynamic Skip Fire in a Connected and Automated Vehicle
  - **University of California, Berkeley**
    - Predictive Data-Driven Vehicle Dynamics and Powertrain Control – From ECU to the Cloud

**Heavy Duty Vehicles**

- **Diesel**
  - **Purdue University**
    - Enabling high-efficiency operation through next-generation controls systems development for connected & automated class 8 trucks
  - **Penn State**
    - Maximizing Vehicle Fuel Economy through the Real-Time, Collaborative, and Predictive Co-Optimization of Routing, Speed, and Powertrain Control
NEXTCAR Industry Ecosystem

OEMs
- TOYOTA
- GM
- Cummins
- HYUNDAI
- VOLVO
- TRUCKS USA

Tier-1 Suppliers
- BOSCH
- Delphi Technologies
- APTIV

System integrators, CAV service providers and others
- TULA
- Sensys Networks
- Peloton
- US Hybrid
- WORKHORSE
External Stakeholders at 2019 Annual Review

Government

OEMs

Tier-1 Suppliers and Equipment Manufacturers

Testing Services

Energy Providers

Mobility Services

NGO/Consultancy
**NEXTCAR Timeline and Critical Milestones**

**Approximate Program Timeline**

- **2016:** Program Development
- **2017:** Program Kickoff
- **2018:**
  - Year-1: Vehicles acquired and connectivity features implemented
  - Year-2: Intermediate energy consumption improvement demonstrations
  - Year-3: Final demonstrations to meet program goals (~20% energy consumption improvement)
- **2019:** Field Demonstration Days
- **2020:**
How relevant is NEXTCAR today?

Commuter Changes
More people are driving cars than taking public transit as lockdowns ease

- Average driving
- Average transit

The Road Back
Chinese monthly auto sales rose for the first time in almost two years in April

- Year-on-year change in China monthly auto sales

Source: Bloomberg News calculation based on Mobility Trends data for 27 cities in Asia, Europe, and Americas

Source: China Association of Automobile Manufacturers
NEXTCAR Program Level Results (to date)

- **Point 1** – bear in mind that results are vehicle-specific, vehicle duty cycle, traffic density, technology, penetration rate, weather specific.

- Not all efficiencies are additive, (but some are).

- These results are presented without context.
  - Results between teams and technologies are not directly comparable (see **Point 1** above).
  - Some results are simulated, some experimental (including HIL, DIL, on-road), some real-world…
### Potential Efficiency Improvements (%)

<table>
<thead>
<tr>
<th>NEXTCAR Technology</th>
<th>MTU</th>
<th>GM</th>
<th>OSU</th>
<th>SwRI</th>
<th>UD</th>
<th>UM</th>
<th>UCB</th>
<th>UMN</th>
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</thead>
<tbody>
<tr>
<td>Eco-Routing</td>
<td>2-21</td>
<td>7</td>
<td></td>
<td>0-35***</td>
<td>7.7-13.8</td>
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<td>12.6-14</td>
<td>12.1</td>
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<tr>
<td>Eco-AND</td>
<td>2-10</td>
<td>8</td>
<td>4-14</td>
<td>0-9.8</td>
<td>17.8</td>
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<td>31²</td>
<td>9.6-22.9</td>
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<tr>
<td>Eco-Driving/Cruise</td>
<td>1-7</td>
<td>10-14</td>
<td>13-16*</td>
<td>10-13*</td>
<td>20</td>
<td>12-14</td>
<td>6.8-15.8</td>
<td>0-12.8</td>
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<tr>
<td>Powertrain Optimization</td>
<td>5-12¹</td>
<td>2-4**</td>
<td></td>
<td>4.9</td>
<td>12</td>
<td>2-7</td>
<td>9</td>
<td>20.1-21.8</td>
<td>8.5-10.5</td>
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<tr>
<td>Thermal System</td>
<td>4-7</td>
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<td>2-8</td>
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<tr>
<td>Compact Platooning</td>
<td>1-7</td>
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<td>0-15</td>
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<td>Intelligent HVAC</td>
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<td>CACC</td>
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<td>2.6-13</td>
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<tr>
<td>Eco-Stop and Launch (bus application)</td>
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<td>10.9-22.9</td>
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</tr>
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</table>

*Eco-driving does include power-split, ** Indicates improvement only by leveraging dynamic skip firing (DSF), Eco-routing includes power-split optimization over the long horizon
¹MTU powertrain optimization includes optimization of drive unit as well as PHEV blending
²Charge depleting mode, with an 8.5% increase in travel time on 2.5km arterial

**Bear in mind Point 1!**
Technology Acceleration Model

PROGRAM DEVELOPMENT CYCLE

ENVISION
- Program Conception (Idea/Vision)
- Workshop
- Program Approval

ENGAGE
- FOA Development & Issuance

ESTABLISH
- Project Selection
- Contract Negotiations & Awards

EXECUTE
- Ongoing Technical Review
- Project Handoff

EVALUATE
- Proposal Rebuttal
- Merit Review of Proposals
NEXTCAR Summary

- NEXTCAR has achieved **significant results** across a range of technologies.
- The motivation for NEXTCAR is **more relevant** than ever right now.
- Commercialization success is the **next critical step**.

- NEXTCAR Field Demonstration Days in September/October at ACM?
- Other avenues for dissemination of information – conferences, workshops, papers, demonstrations?

- ARPA-E is always interested in energy efficiency technologies – anticipate OPEN 2021?

- *Bon voyage!* Be safe, be healthy and do good things. See you down the road.

These slides will be shared soon.