ALPHA UPDATE FOR NAS PHASE 3 COMMITTEE ON FUEL ECONOMY TECHNOLOGIES

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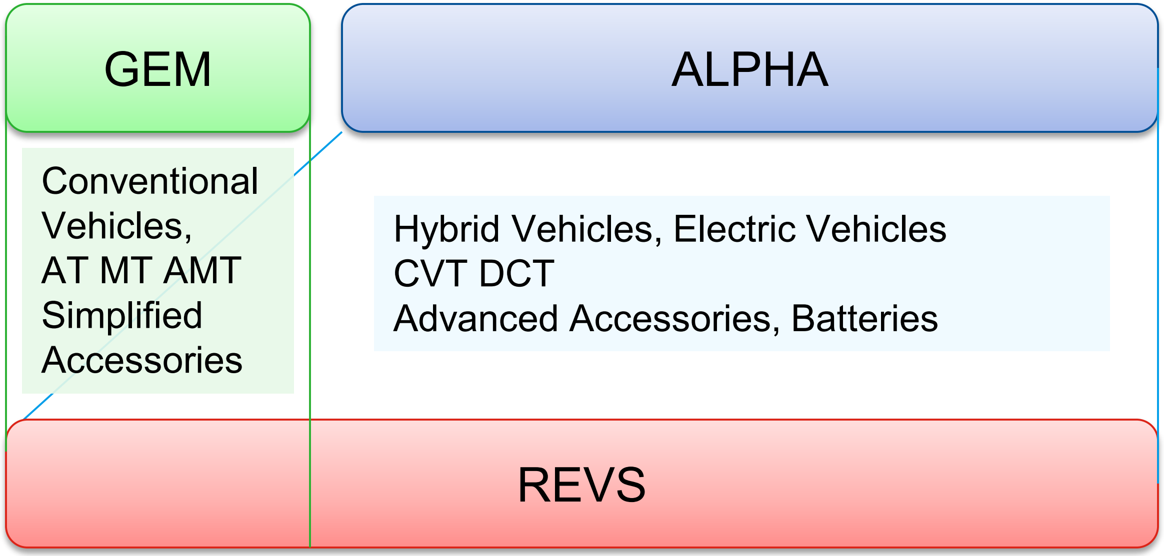
TOPICS

- Brief review of prior work
- Update on large scale modeling development
- Update on EV/48V Hybrid Modeling
- Future work

BRIEF REVIEW OF PRIOR WORK

- ALPHA and GEM (The Greenhouse Gas Emissions Model certification tool for Heavy Duty GHG) share a common platform called REVS
- REVS defines the data structures, scripts and functions as well as the models which comprise the vehicle and component models

GEM is a certification tool, not a product design tool or a research tool like ALPHA



BRIEF REVIEW OF PRIOR WORK

- Benchmarking and GEM / ALPHA Development Papers

  - Newman, K., Dekraker, P., Zhang, H., Sanchez, J. et al., "Development of Greenhouse Gas Emissions Model (GEM) for Heavy- and Medium-Duty Vehicle Compliance," SAE Int. J. Commer. Veh. 8(2):2015, doi:10.4271/2015-01-2771.
  - Newman, K., Kargul, J., and Barba, D., "Benchmarking and Modeling of a Conventional Mid-Size Car Using ALPHA," SAE Technical Paper 2015-01-1140, 2015, doi:10.4271/2015-01-1140.
  - Newman, K., Kargul, J., and Barba, D., "Development and Testing of an Automatic Transmission Shift Schedule Algorithm for Vehicle Simulation," SAE Int. J. Engines 8(3):2015, doi:10.4271/2015-01-1142.
  - Newman, K., Doorlag, M., and Barba, D., "Modeling of a Conventional Mid-Size Car with CVT Using ALPHA and Comparable Powertrain Technologies," SAE Technical Paper 2016-01-1141, 2016, doi:10.4271/2016-01-1141.
  - Paul Dekraker, Daniel Barba, Andrew Moskalik, Karla Butters, "Constructing Engine Maps for Full Vehicle Simulation Modeling ," SAE Technical Paper 2018-01-1412, 2018, doi:10.4271/2018-01-1412.
  - Dekraker, P., Kargul, J., Moskalik, A., Newman, K. et al., "Fleet-Level Modeling of Real World Factors Influencing Greenhouse Gas Emission Simulation in ALPHA," SAE Int. J. Fuels Lubr. 10(1):2017, doi:10.4271/2017-01-0899.
  - Dekraker, P., Stuhldreher, M., Kim, Y. (SwRI), "Characterizing Factors Influencing SI Engine Transient Fuel Consumption for Vehicle Simulation in ALPHA," SAE Technical Paper 2017-01-0533, 2017, doi:10.4271/2017-01-0533.

BRIEF REVIEW OF PRIOR WORK

- ALPHA Research and ALPHA Supported Papers
  - Ellies, B., Schenk, C., and Dekraker, P., "Benchmarking and Hardware-in-the-Loop Operation of a 2014 MAZDA SkyActiv 2.0L 13:1 Compression Ratio Engine," SAE Technical Paper 2016-01-1007, 2016, doi:10.4271/2016-01-1007.
  - Kargul, J., Moskalik, A., Barba, D., Newman, K. et al., "Estimating GHG Reduction from Combinations of Current Best-Available and Future Powertrain and Vehicle Technologies for a Midsized Car Using EPA’s ALPHA Model," SAE Technical Paper 2016-01-0910, 2016, doi:10.4271/2016-01-0910.
  - Newman, K. and Dekraker, P., "Modeling the Effects of Transmission Gear Count, Ratio Progression, and Final Drive Ratio on Fuel Economy and Performance Using ALPHA," SAE Technical Paper 2016-01-1143, 2016, doi:10.4271/2016-01-1143.
  - Moskalik, A., Hula, A., Barba, D., and Kargul, J., "Investigating the Effect of Advanced Automatic Transmissions on Fuel Consumption Using Vehicle Testing and Modeling," SAE Int. J. Engines 9(3):2016, doi:10.4271/2016-01-1142.
  - SoDuk Lee, Jeff Cherry, Michael Safoutin, Anthony Neam, Joseph McDonald, Kevin Newman, "Modeling and Controls Development of 48V Mild Hybrid Electric Vehicles," SAE Technical Paper 2018-01-0413, 2018, doi:10.4271/2018-01-0413.
  - Kevin Bolon, Andrew Moskalik, Kevin Newman, Aaron Hula, Anthony Neam, Brandon Mikkelsen, "Characterization of GHG Reduction Technologies in the Existing Fleet," SAE Technical Paper 2018-01-1268, 2018, doi:10.4271/2018-01-1268.
  - Andrew Moskalik, Kevin Bolon, Kevin Newman, Jeff Cherry, "Representing GHG Reduction Technologies in the Future Fleet with Full Vehicle Simulation," SAE Int. J. Fuels Lubr. 11(4):469-482, 2018, doi:10.4271/2018-01-1273.
  - Schenk, C. and Dekraker, P., "Potential Fuel Economy Improvements from the Implementation of cEGR and CDA on an Atkinson Cycle Engine," SAE Technical Paper 2017-01-1016, 2017, doi:10.4271/2017-01-1016.

LARGE SCALE SIMULATION CAPABILITY

- Since the NAS Phase 2 Committee presentation in 2014, ALPHA has been upgraded with the capability to run large scale simulations
- Simulations are run across multiple machines and multiple processors over a local area network using a Python distributed computing package
- A complete set of runs for the MTE was over 250,000 simulations and provided millions of results when interpolated, for example using response surface equations (RSEs)
- SAE Journal of Fuels and Lubricants paper "Representing GHG Reduction Technologies in the Future Fleet with Full Vehicle Simulation" 2018-01-1273 discusses the large scale simulation and RSEs

UPDATE ON EV/48V HYBRID MODELING

- ALPHA has EV modeling capability that will be refined
  - Past focus was conventional vehicle modeling
  - Increased sales and viability of EVs renews the focus on EV modeling
  - Current ALPHA simulations rely on publicly available motor/inverter efficiency maps
  - NCAT will be benchmarking the Chevy Bolt to inform more detailed modeling efforts
- ALPHA has mild/48V hybrid modeling capability
  - In past EPA ALPHA analyses there were no 48V hybrids in production
  - The 48V hybrid vehicle control strategy was based in part on the Chevy Malibu ECO mild hybrid
  - EPA will benchmark the 48V Jeep Wrangler in order to update ALPHA 48V modeling efforts

Image from
https://www.greencarcongress.com/2019/01/20190117-ecodrive.html

GM's EV PROGRESS: COMPARING ELECTRIC CHEVIES		
	2014 Spark EV	*2017 Bolt EV*
Vehicle Class	A	B
Curb wt (kg)	1342	1625
0-60 mph, s	7.5	<7
0-30 mpg, s	3.1	2.9
Max. launch grade, %	28	30
EPA label range, mi	82	200
Battery chemistry	Li-ion	Li-ion, nickel-rich
Battery nominal energy	20 kW·h	60 kW·h
Battery mass	260 kg	436 kg
Max. battery power	120 kW	150 kW
Battery nominal voltage	360V	350V
Battery cooling control	Liquid active	Liquid active
Peak axle torque, N·m	1710	2500
Gear ratio	3.87	7.05
Drive unit mass, kg	68	76
Lubricant type	Dexron VI	Dexron VI
Total ATF volume, L	4.2	2.9
Motor peak power density, W/cm3	18.5	28.8
Peak torque density, N·m/cm3	0.09	0.07
Peak torque, N·m	540	360
Max speed, rpm	4500	8810
Rated current, Arms	450	400
Nominal DC bus voltage, V	350	350
Motor stack length, mm	125	125
Motor outer diameter, mm	213	204
Number of poles	8	8

Further details can be found in SAE Technical Paper: Design of the Chevrolet Bolt EV Propulsion System, http://papers.sae.org/2016-01-1153/.

INITIAL CHEVY BOLT MODELING

- **2017 Chevy Bolt was the first 200 mi+ range EV under $40k, just under $30k with available $7.5k tax rebate for the base model**
- **ABC (lbs) = 28.4, 0.2018, 0.01948**
- **ETW (lbs) = 3785, 3583 lbs curb**
- **0-30 2.7s, 0-60 6.3s (Motor Trend)**
- **238 mile range (255 city / 217 hwy)**
- **119 MPGe sticker**
- **150 kW motor**
- **60 kWh pack, 288 cells (96s3p) 350V**

INITIAL CHEVY BOLT MODELING

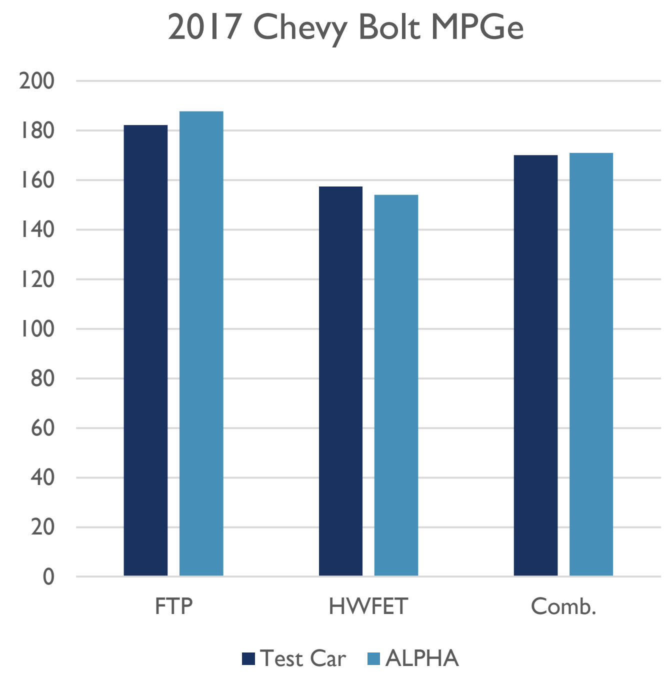
- **Initial modeling results using default motor maps (Nissan Leaf / ORNL) are reasonable**
- **No in-vehicle data available for comparison**
- Range results assume 80% usable battery capacity
- EPA benchmarking data will be used to refine the results in the future

MPGe			
Test Cycle	***Certification***	***ALPHA***	***Diff***
FTP	182.2	187.8	3.1%
HWFET	157.4	154.1	-2.1%
Comb.	170.1	171.0	0.5%

Range (miles)*			
Test Cycle	***Certification***	***ALPHA***	***Diff***
UDDS	255.1	270.6	6.1%
HWFET	217.4	219.1	0.8%

* Assuming 80% usable battery capacity

Performance		
	Motor Trend	***ALPHA***
0-30 secs	2.7	3.11
0-60 secs	6.3	6.97
1/4 mi secs	14.9	15.6
1/4 mi speed	93.1	90.9



FUTURE WORK

- EV modeling updates
  - Update EV motor/generator model to account for continuous versus intermittent operating envelope and performance
  - Gather data from benchmarking to better understand accessory loads and temperature effects on vehicle range and performance
- Considering possible open source ALPHA release
  - A public release would increase transparency and help meet Agency open source software goals
  - Release would use tools common to other open source projects
  - Have started writing user documentation
  - Considering partnering with key stakeholders during the development process of a public release
  - Considering a graphical user interface for ease of use
  - Considering refactoring the model to eliminate an expensive required software license to lower the cost of entry for users
  - No set date for release at this time

QUESTIONS?

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