Task Order 0003 under
Contract DTNH22-13-D-00298

Peer Review of "Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #3"*

PEER REVIEW REPORT
June 18, 2015

Submitted to:
U.S. Department of Transportation
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Washington, DC 20590
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*Note: NHTSA changed the title of this report to "Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study - Report #2" prior to final publication.

CONTENTS

1.0 INTRODUCTION

This report documents the results of an independent external peer review of the draft publication *Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #3,* developed by Southwest Research Institute (SwRI) for the National Highway Traffic Safety Administration (NHTSA). (Note: NHTSA retitled this report as "*Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study – Report #2*" prior to final publication [see Section 2.0]).

Eastern Research Group, Inc. (ERG, a contractor to NHTSA) organized this review and developed this report. The report provides background about the review (Section 2), describes the review process (Section 3), and presents reviewer comments organized by charge question (Section 4). Appendices A, B, and C, respectively, provide reviewer curriculum vitae, the charge to reviewers, and the individual comments submitted by each of the six reviewers.

2.0 BACKGROUND

In September 2012, NHTSA competitively awarded a contract to SwRI to conduct research in support of the next phase of Federal fuel efficiency (FE) and greenhouse gas (GHG) standards. Tasks included determining the baseline fuel efficiency and emissions levels and technologies of current model year commercial medium- and heavy-duty on-highway vehicles and work trucks, as well as projections of Phase 2 (post-2018 model year) fuel efficiency and emission reduction technologies. The scope encompassed technologies for chassis and final-stage manufacturer vehicles and trailers, maintenance cost, material application, future design, electric and hybrid propulsion systems, capital investment, retail cost/payback, and any other applicable advanced technologies. Estimates of the costs, fuel savings effectiveness, availability, and applicability of technologies were done for each individual vehicle class category (e.g., segment).

The resulting report series consists of three sequential reports. All three reports are from the same project, and involve the same technologies, engines, and vehicles; however, due to their large size, they were separated into three documents to facilitate review and publication. This review covers the third of these reports. The third report describes the results of a task in which SwRI performed sweeps of vehicle parameters to determine their effect on vehicle fuel consumption. These sweeps included changes to the aerodynamic drag coefficient (Cd), the tire rolling resistance (Crr), the vehicle empty weight, and the axle ratio. Vehicle performance and fuel consumption were evaluated over a range of driving cycles.

It is important to note that NHTSA changed the numbering in the title of the third report prior to publication, as shown in bold in the table on page 2. In preparing their written comments (presented in Section 4.0 and Appendix C of this document) on the third report, reviewers consistently used the numbering in the <u>draft report titles</u> when referring to the first, second, and third reports in this series. Thus, they refer to the first report as Report #1, the second (Cost Study) as Report #2, and the third (the review document) as Report #3. See the table on page 2.

3.0 PEER REVIEW PROCESS

3.1 Reviewer Search and Selection

For this review, at NHTSA's request, ERG contracted with the same six reviewers that ERG had independently selected to review the first report (Report #1) in this series. ERG's Report #1 search and selection process involved identifying, screening, and selecting six reviewers who had no conflict of interest (COI) in performing the review and who collectively met the following technical selection criteria provided by NHTSA:

Expertise with MD/HD Vehicles

- Fuel consumption/GHG reduction technologies for MD/HD on-highway vehicles and work trucks, including their engines and trailers.
- MD and/or HD truck vocation and duty cycles.
- Global fuel economy/GHG regulations.
- Engine fuel consumption map simulations (gasoline and diesel).
- Whole vehicle fuel consumption simulations (Greenhouse Gas Emissions Model [GEM] or comparable software) over vehicle drive-cycles (Class 2b-8 trucks, including combination tractors, heavy-duty pickup trucks and vans, and vocational vehicles).
- Fuel economy/emissions regulatory test procedures and drive cycles.
- Hybrid vehicle technologies.
- Fuel price comparison.

Expertise with LD Vehicles

- Fuel consumption/GHG reduction technologies.
- Global fuel economy/GHG regulations.
- Engine fuel consumption map simulations (gasoline and diesel).
- Whole vehicle fuel consumption simulations over vehicle drive-cycles.
- Fuel economy/emissions regulatory test procedures and drive cycles.
- Hybrid vehicle technologies.
- Fuel price comparison.

From among the qualified candidates, ERG selected six reviewers who collectively best met the selection criteria and had no conflict in performing the review. NHTSA verified that these experts were appropriately qualified.

Draft and Final Report Titles for the Three Sequential Reports*

Draft Report Title	Final Report Title
Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #1	Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study – Report #1
Costs of Medium- and Heavy-Duty Vehicle Fuel Efficiency and Emissions Reduction Technologies for MY 2019 – 2022 *(informally referred to as Report #2)*	Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Cost Study
Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – **Report #3**	Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study – **Report #2**

*The report that was the subject of this peer review is shown in the shaded cell.

The selection criteria for Report #3 were identical to those for Report #1, with a preference for candidates who had reviewed Report #1. All six Report #1 reviewers confirmed that they were available and had no conflict in reviewing Report #3. Biographies for the Report #3 reviewers are provided below. Their curriculum vitae/resumes are provided in Appendix A.

Dr. Matthew J. Barth, Yeager Families Professor at the College of Engineering, University of California-Riverside (UCR). Dr. Barth is part of the intelligent systems faculty in Electrical Engineering and is also serving as the Director for the Center for Environmental Research and Technology (CE-CERT), UCR's largest multi-disciplinary research center. His research focuses on applying engineering system concepts and automation technology to transportation systems, and in particular how it relates to energy and air quality issues. His current research interests include intelligent transportation systems (ITS) and the environment; transportation/emissions modeling; vehicle activity analysis; advanced navigation techniques; electric vehicle technology; and advanced sensing and control. Dr. Barth is active with the U.S. Transportation Research Board serving in a variety of roles in several committees, including the Committee on ITS and the Committee on Transportation Air Quality. He was awarded the TRB Pyke Johnson Award for TRB outstanding paper in 2007. In 2011, he was one of the winners of the Connected Vehicle Technology Challenge sponsored by U.S. Department of Transportation's Research and Innovative Technology Administration (RITA). He has also served on a number of National Research Council (NRC) Committees.

Ph.D., Electrical and Computer Engineering, University of California-Santa Barbara, 1990
M.S., Electrical and Computer Engineering, University of California-Santa Barbara, 1986

Dr. William de Ojeda, Director of Engineering, WM International Engineering, LLC. Dr. de Ojeda joined WM International Engineering in 2014 and is currently responsible for development of fuel injection and charge air systems for advanced diesel, gasoline, natural gas, dual fuel, and alternative fuel powertrains. His work includes design, prototyping, controls, and benchmarking. He was previously with Navistar, Inc. for 17 years where he was a Senior Product Engineer of advanced technologies and Manager of advanced combustion and controls. In 1990, Dr. de Ojeda received the Stefano Excellence Capstone Design Award for "A Microcomputer-Interfaced Steam Turbine Test Stand."

Ph.D., Mechanical and Aerospace Engineering, Illinois Institute of Technology, 1996
M.Sc., Mechanical and Aerospace Engineering, University of Virginia, 1992

Mr. Dana M. Lowell, Senior Vice President & Technical Director, M.J. Bradley & Associates LLC (MJB&A). Mr. Lowell has 25 years professional experience in the transportation and government sectors. He has worked in MJB&A's advanced vehicle technology group since 2004, providing strategic analysis, project management, and technical support to mobile source emissions reduction programs. His mobile source project work includes evaluation and implementation of advanced diesel emissions controls, alternative fuels, and advanced hybrid and fuel cell electric drives, as well as development and implementation of diesel emissions testing programs for a range of on-road and non-road heavy-duty vehicle types.

M.B.A., co-major in Management and Operations Management, New York University, 1995
B.S., Mechanical Engineering, Princeton University, 1985

Dr. Shawn Midlam-Mohler, Assistant Professor, Department of Mechanical and Aerospace Engineering, Ohio State University (OSU); Associate Director, OSU's Simulation Innovation and Modeling Center; OSU-CAR Associate Fellow, Center for Automotive Research; and Director of OSU Motorsports in the College of Engineering. Dr. Midlam-Mohler maintains an active research program focused in the area of model-based design of complex systems. His teaching focuses on automotive technical electives, capstone senior design, and most recently a course on project management and systems engineering. He has also developed a number of courses in his area of expertise for the Department of Energy (DOE) sponsored advanced technology vehicle competition program.

Ph.D., Mechanical Engineering, Ohio State University, 2005

M.S., Mechanical Engineering, Ohio State University, 2001

Ms. Susan M. Nelson, Owner and Managing Member, Blue Stripe Scientific, LLC. Ms. Nelson is a project manager with over 12 years of experience piloting teams in new product research and development (R&D), test development and validation, manufacturing, quality assurance, and public-private research partnerships. Currently as a Project Manager and technical service provider, she assesses approaches to monitor and maintain inflation pressure in heavy-duty vehicle tires, under contract to the North American Council for Freight Efficiency (NACFE). She has defined categories of technologies to permit characterization of diverse product offerings according to common features and functionalities. She is highly familiar with various tire pressure technologies.

M.S., Civil Engineering, Massachusetts Institute of Technology, 1979
B.S., Civil Engineering, Massachusetts Institute of Technology, 1977

Dr. John P. Nuszkowski, Assistant Professor, Mechanical Engineering Program, University of North Florida. Dr. Nuszkowski's research includes vehicle powertrain optimization, in-use vehicle emissions, advanced combustion, alternative fuels, and large-bore diesel emissions reduction. His research goals are to improve vehicle fuel economy by operating vehicles more efficiently and improve air quality by reducing the exhaust emissions from engines and vehicles through improved combustion of petroleum-based fuels and use of alternative fuels. Since 2008, he has conducted research for heavy-duty vehicle and engine performance and emissions.

Ph.D., Mechanical Engineering, West Virginia University, 2008
M.S., Mechanical Engineering, West Virginia University, 2005

3.2 Conducting the Review

ERG provided reviewers with the review document and the charge to reviewers (Appendix B). To kick off the review, ERG organized a 1-hour briefing call. During this call, which was facilitated by ERG, NHTSA provided background about the purpose and development of the review document, and reviewers had the opportunity to ask questions of clarification regarding the charge and review process.

After this call, reviewers worked individually (i.e., without further contact with other reviewers or NHTSA) to prepare written comments in response to the charge questions. During this time, two reviewers sent additional questions of clarification to ERG. ERG forwarded these questions to NHTSA and provided NHTSA's responses to all six reviewers.

Reviewers completed their reviews and submitted their written comments to ERG, and ERG forwarded them to NHTSA. Both ERG and NHTSA checked the comments to ensure that reviewers had responded clearly to all charge questions. NHTSA requested one clarification, and ERG forwarded this request to the relevant reviewer. ERG added the clarification to the reviewer's comments and then prepared this peer review report. Section 4 of this report presents reviewer comments organized by charge question, and Appendix C provides the comments by reviewer. In both cases, comments are presented exactly as submitted, without editing, summarizing, or correction of typographical errors (if any).

4.0 REVIEWER COMMENTS ORGANIZED BY CHARGE QUESTION

This section presents reviewer comments organized by charge question. Comments are copied directly from written comments as submitted by each reviewer and presented in Appendix C.

4.1 Introduction

4.1-1 Does the introduction in Section 1 provide sufficient background on the overall program and the two prior reports in this series to allow this report to be read as a stand-alone document?

Barth

- The executive summary does a reasonable job of summarizing the overall report, but it is chock full of a lot of acronyms and defined "packages" that the reader really won't know about until they read the actual report. As such, the executive summary does not really stand on its own. It reads more like a conclusion after you read the whole report, as opposed to an executive summary that would let a layman know the gist of the report. I'm not sure if that is under the purview of this review.

- The introduction explains the "lay of the land" in terms of the NHTSA process and what the charge is leading to this report #3. It refers to report #1, in terms of updating the results and providing the relationship of this report #3 to the past report #1. However, there is very little mention of report #2 in the intro. Although we already know about Report #2 and what it is all about, a general reader of this report #3 might be wondering about it. A sentence describing it in the intro would help.

- The intro (and section 3) discusses the "sweeps" it does of different parameters in the simulations. This term seems to be a bit of jargon, in academic papers we often describe these as a "parameter sensitivity analyses". I think simply stating that a "sweep" is essentially a "sensitivity analysis" would be useful, and then continue to call it sweeps after that.

- Overall, the intro of report #3 is sufficient to allow for report #3 be read as a stand-alone document.

de Ojeda

The introduction is rather brief. It is recommended that Section 1 be expanded to:

- Include a description of the "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles". This may be done via table (see below). The text could include applicability: combination tractors, vocational vehicles, HD pickups and vans. May also for completeness includ US EPA SmartWay requirments (tractor and trailer aerodynamics, low rolling resistance tires) and applicability (53' or longer trailers or box type). It may also include motivation (improved emissions and fuel savings via adoption of new technologies, harmonize standards). Finally, a timeline for adoption may be included.

HD Combination Tractor Vehicle Standards (gCO2/ton-mile)						
	2014-2016 MY			2017 MY and beyond		
	Class 7	Class 8		Class 7	Class 8	
		Day Cab	Sleeper Berth		Day Cab	Sleeper Berth
Low Roof	107	81	68	104	80	66
Mid Roof	119	88	76	115	86	73
High Roof	124	92	75	120	89	72

Vocational Vehicle CO2 Standard (gCO2/ton-mile)			
	LHD Class 2b-5	MHD Class 6-7	HHD Class 8
2014 MY	388	234	226
2017 MY	373	225	222

Final HD Diesel Engine Standards (gCO2/bhp-hr)					
	LHD (2b-5)	MHD (Class 6-7)		HHD (Class 8)	
		Vocational Veh	Tractors	Vocational Veh	Tractors
2014-2016 MY	600	600	502	567	475
2017 and Later	576	576	487	555	460

- Include a summary of the engines and vehicles per Table 3.1 VEHICLE AND ENGINE CLASSIFICATION from Report 1 (page 32), as noted below.

TABLE 3.1 VEHICLE AND ENGINE CLASSIFICATION

Class	Vehicle	Diesel	Gasoline	Base Transmission
2b	Ram Pickup	Cummins 6.7 Liter 385 HP (base), 4.5 Liter 256 HP	3.5 L V-6, 6.2 L V-8	6-Speed Automatic
3				
4				
5	F-650 Tow Truck	Cummins 6.7 Liter 300 HP (base), 4.5 Liter 256 HP	3.5 L V-6, 6.2 L V-8	5-Speed Automatic
6	T270 Box Truck			
7				
8	T700 Tractor-Trailer	Detroit 14.8 L DD15 (base), 12.3 L Derivative	None	10-Speed AMT

- Present the major findings from Report 1 (list the technologies examined, highlight which technologies made it to this stage of the study);

- Report 2 is a cost estimate study. It is not clear what role this has played in the down-selection process. If it has, please indicate how it did.

Lowell

- Yes, section 1 provides sufficient background for this report to be read as a stand-alone document.

Midlam-Moher

The report provides a sufficient overview of Report #1 and the overall program. There is no reference to Report #2 that I could find (e.g. searching for ‘#2’ or ‘second’ yields no hits.)

Nelson

Report #3 can be strengthened as a stand-alone report with the inclusion of the following in Section 1.0:

- A brief paragraph indicating the *principal* objective and authoring organization of each of the three individual reports. For example, the primary topic of the first report is to analyze the potential of medium- and heavy-duty truck engine and vehicle technologies to deliver reductions in fuel consumption during the 2014-2018 Phase 1 timeframe, introducing each technology one-by-one into a baseline engine and vehicle configuration. The second report evaluates costs associated with implementing fuel savings upgrades, including a few associated technologies – such as automatic tire inflation systems - that were not considered in the earlier engine and vehicle performance simulations. Finally, the third report establishes new engine and vehicle baselines for the post-2018 timeframe, and evaluates the potential additional reductions in fuel consumption that could be obtained by grouping together compatible technologies.

- A single table which presents the vehicles selected for analysis, the vehicle applications, the weight class and GVWR represented by each vehicle, the engine type(s) which were studied for each vehicle, and the drive cycles used in simulations of each vehicle to obtain fuel consumption predictions.

Nuszkowski

The introduction provides sufficient background on the overall program.

4.1-2 Does the introduction adequately detail the report contents?

Barth

- Although it isn't crucial, the intro doesn't say anything about the conclusions of section 6, nor does it mention the contents of the appendices. The intro simply drops off abruptly right after describing section 6. A few more sentences might help here.

de Ojeda

Yes. The report has a brief but informative summary of the sections that follow.

Lowell

Yes, the introduction adequately describes the report contents.

Midlam-Moher

Yes.

Nelson

The Introduction provides a clear and concise overview of the contents of the report. Other comments on Section 1 are listed below.

- It should be highlighted that Section 2 technologies include a study of hybrid solutions for the pickup truck. Hybrid solutions were not simulated in Report #1.
- The discussion of bottoming cycle and recuperator solutions should be moved to the paragraph describing Section 2, instead of being included in the description of Section 3.
- In addition to predicting the degree of fuel savings that can be obtained through specific combinations of key technologies, Section 1.0 describes an ambition to identify technology combinations that are directly (linearly) additive, those which are additive but which demonstrate non-linear interactions that may not be predictable from simulations of individual technologies, and those which are in opposition. An analysis of technology interactions has not been explicitly presented in the report. Some clarification of how this objective will be accomplished, either by including a report section, or suggesting future research directions, should be provided.

Nuszkowski

The hybrid technologies, from Section 2, were not introduced. All other sections were introduced adequately.

4.2 Combined Benefits Simulations

4.2-1 Please comment on Section 2. The purpose of this section was to explore which technologies provide benefits that are additive, which provide benefits that are not additive, and whether any technologies are synergistic, and to quantify the overall fuel consumption improvement from combining multiple technologies. Please comment on the quality, scope, and rigor of methodology used for the performance analysis of the vehicle and engine technology combinations (packages). Is the methodology clearly described and appropriate to the aims of the project? Is it sufficiently comprehensive and robust to provide credible results?

Barth

- In section 2, it is stated that "NHTSA and SwRI agreed on combinations of technologies", but little or no detail is provided on how these combinations were chosen. It would be good to explain what were the guiding principles involved in terms of figuring out what combinations would be best, or most likely. The choice of the combinations of technology is a very important step and very little is said about it. The reader is left wondering if there are other combinations that maybe made sense, and deserved some analysis.

- In the technology combinations, there are a lot of acronyms, which is fine, since they are defined in the acronym list early in the report. However, the authors I think abbreviate previous packages (e.g., P1, and P2) but the reader isn't exactly clear if this is the case. It would be good to simply say what is meant by P1, P2, etc…

- It is understood that the main purpose of this effort is to evaluate fuel economy improvements and reductions of GHG emissions. As such, GT-POWER and the associated simulation tools are sufficient to make a good determination, given the different assumptions that are made along the way. However, there is very little discussion on the tradeoffs between control of pollutant emissions and fuel economy savings. In addition to the fuel economy improvement rules by NHTSA, vehicle and engine manufacturers must also comply with pollutant emission regulations. GT-POWER and the associated simulation tools do not examine the pollutant side of the equation, so there is a bit of a concern that by implementing certain technologies (or combinations of technology) for fuel economy, what would the effect be on pollutant emissions? Combined fuel economy and pollutant emissions analysis would be more appropriate. But it seems that this is outside of the scope of the project.

- In terms of drive cycles, I think report #1 discusses how these certain cycles were selected, based on providing a good range of operations for the different vehicle types. However for simulation analysis, an interesting approach would be to examine *vehicle activity data* (i.e., real world trajectory data from subsets of these vehicles) from the vehicles in question, and then select and compare driving cycles that are representative of the vehicle activity data itself. The number of publically-accessible vehicle activity data sets is increasing rapidly and should be utilized if at all possible (e.g., NREL's activity database described at http://www.nrel.gov/transportation). Better yet, rather than use driving cycles at all, why not run entire vehicle activity datasets (appropriate for the vehicle technology) directly through the model(s)? The computational time of these models is not that severe, so processing all of these data should not take too much time. That way you skip any controversy regarding whether the driving cycles are representative or not.

- It is possible for the reader to determine which technologies provide additive benefits, which combinations do not, etc., by examining the data (tables and graphs). There is some commentary about the different combinations, but the report could be improved if a paragraph was inserted after each vehicle type (DD15, T700, etc.) that explicitly stated what technologies were additive, which combinations did not work well, etc. The descriptions provided only touch on specific combinations; but there isn't any analysis that talks about how the different combinations compare. (actually, this is done more so for the later vehicles types, e.g., F-650, etc., but not so much for the initial vehicle types)

- On page 19, there is a reference to the SuperTruck program, but little info is given. A reference should be provided…
- Minor issue: the figure 2.6 has the black baseline line at 1% rather than at 0%, not sure if that is a graphical problem or if that was done on purpose?
- Minor: on page 40, not sure why "Vehicle Technology Combinations" is capitalized;
- In table 2.20 on page 44, it isn't clear why the "2019 ISB" is in there twice. Isn't this the baseline that things are being compared to? Or is this the diesel comparison? This needs a bit more explanation in the text, it is confusing to the reader.
- For figures 2.23 and 2.24, why is the scale of the graph chosen to be 20%, when all of the percent savings are around 12% or less? The other graphs had better scaling, these figures seem different.
- Section 2.3.11 seems to be missing text that interprets the results of table 2.23. The different percent FC benefits are in the data, but there should be some text that interprets this. It would also be interesting to compare this to the other technologies discussed so far in the report.
- Overall, the methodology described in section 2 is for the most part clearly described and appropriate, with some caveats as described above. The results are sufficiently comprehensive and robust.

de Ojeda

The section is well organized. Tables describe technology combinations for each engine and vehicle. This reviewer has checked the references between tables and descriptions. The report is very clear. There are only minor cases where there could be more clarity. Here may be one case: In some instances the report indicates the complexity of the packages assembled. Package 5 in page 16 is deemed very complex but it is not clearly indicated why. This particular package however may not be as complex however as packages 3, 3a, 3b… 3f that incorporate WHR. The report may want to capture the complexity of each of the packages (see suggestion below).

The methodology is adequate. It is comprehensive and the work presented provides credible results. The systematic approach of stepping through "package" scenarios is very organized and easy to follow.

Please update and correct the following typos:

- Table 2.7, 2.8, 2.9 have wrong reference to packages.
    - Table 2.7 P8: P2 + … should have been P7 +
    - Table 2.7 P9: P3 + … should have been P8 +
    - Table 2.8 P13: P2 + … should have been P12 +
    - Table 2.8 P15: P3 + … should have been P13 +, also +800 should be +700

- Table 2.9 P17: P2 + … should have been P17 +
- Table 2.9 P20: P3 + … should have been P18 +

- Page 10 states that cycles of Table 2.10 are described in detail Appendix C. This does not appear to be the case. The reader expects time traces of speed and load. Can these be inserted?
- Page 25 2.3.5.9 3.5 V6 Package 18: Package 1 (should be 16) + Lean Burn (3.5 P18)
- Page 26 2.3.5.12 6.2 V8 Package 21: Package 1 (should be 20) + VVA (6.2 P21)
- Page 28, package numbers 2-5 seem mislabeled, they start at 11
- Page 35-36. Figure titles refer to F-650 *(should be T270)*
- Page 50. Reference made to F-650 in section 2.3.9.17 Comparison of the Three Baseline Engines in the F-650 need to be corrected (should be Ram pickup truck)

Suggested improvements: The data may be rearranged to show more clearly the merit of each the technologies and the result of combinations. One way is illustrated in the figure below for the HD DD15 engine and the T700 vehicle, and later for the engines and F-650 vehicle. The tables seeks to:

- Clearly highlight the technology content of each package and provide a better overview of the combinations,
- Put a complexity weight factor for each package alongside the reported fuel benefit. Here GREEN=1, YELLOW=2, RED=3 (the designations are the reviewer's estimations and are inserted primarily for illustration purposes).
- Charts may be drawn indicating the relation between the fuel and complexity index such as indicated below.
- The tables are drawn for one of the drive cycles (NESCAFF for the HD and WHVC for the MD – each at 50% load).

Suggestions on analyzing HD simulation data

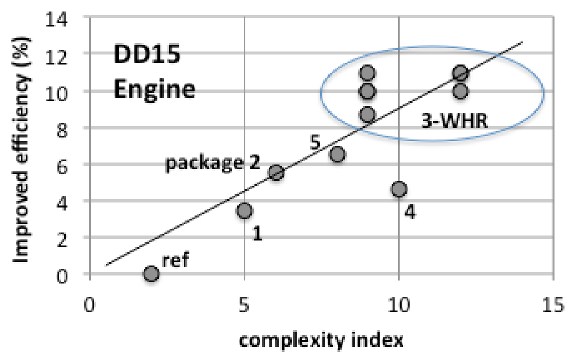
Results shown for NESCAFF – 50% load

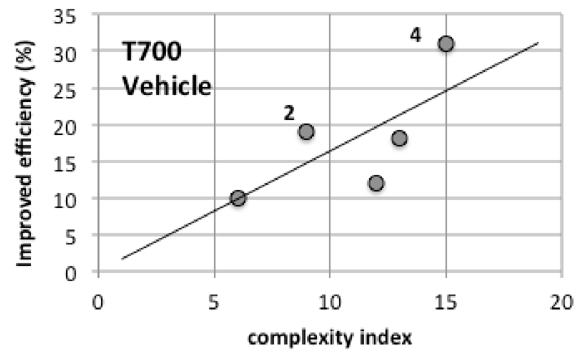
DD15 Engine Technologies in T700

Package	Combustion	Turbocomp	Turbochg	EGR	SCR	flow restrict	FMEP	Downspeed	WHR	WHR-Recup	NESCAFF	Complexity
2011	-	base	Asymetric	base	base	base	base	1368			-2.4	
2019	1%	none	Asymetric	base	base	base	base	1368			0.0	2
1	1%	none	Asymetric	base	base	base	10-35%	1368			3.4	5
2	1%	none	Asymetric	base	base	base	5-17%	1051			5.5	6
3	1%	none	Asymetric	base	base	base	5-17%	1051	Water	-	10.0	9
3a	1%	none	Asymetric	base	base	base	5-17%	1051	R245	-	8.7	9
3b	1%	none	Asymetric	base	base	base	5-17%	1051	R245	x	10.0	12
3c	1%	none	Asymetric	base	base	base	5-17%	1051	MeOH	-	11.0	9
3d	1%	none	Asymetric	base	base	base	5-17%	1051	MeOH	x	11.0	12
3e	1%	none	Asymetric	base	base	base	5-17%	1051	EtOH	-	10.0	9
3f	1%	none	Asymetric	base	base	base	5-17%	1051	EtOH	x	11.0	12
4	1%	none	Fix	None	high Eff	base	10-35%	1368			4.6	10
5	1%	base	Asymetric	base	base	reduced	5-17%	1051			6.5	8

T700 Truck Technology Combination Results

	Cd	Crr	Weight	AC power	Chassis fric	Axles	Transm	Engine	SCR	WHR	NESCAFF	Complexity
	base	base	base	base	base	base	base	base	base	none	0.0	0
1	-15%	-10%	3%	base	base	base	base	base	base	none	9.9	6
2	-25%	-30%	-6.50%	base	base	base	base	base	base	none	19.0	9
3	-15%	-10%	3%	-40%	-20%	6x2	18-AMT	base	base	none	12.0	12
4	-25%	-30%	base	-40%	-20%	6x2	18-AMT	DD15-3b	base	install	31.0	15
5	-15%	-10%	3%	-40%	-20%	6x2	18-AMT	DD15-5	high eff	none	18.0	13



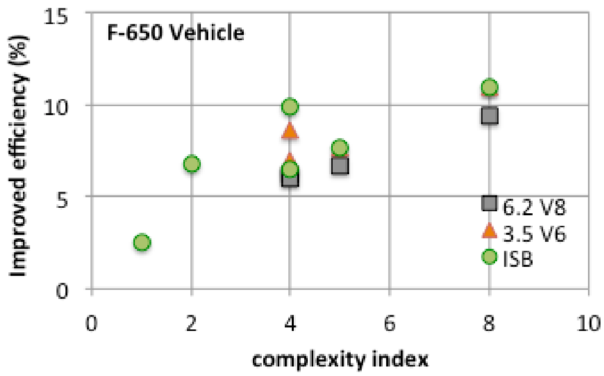


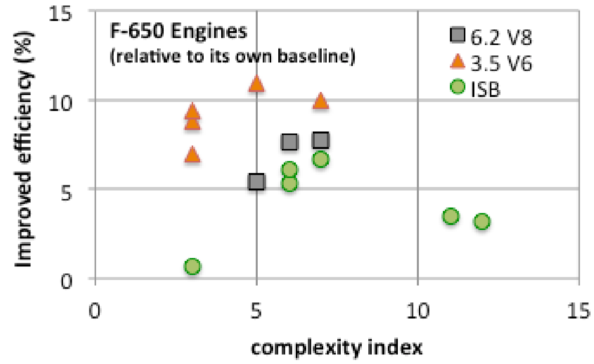
Suggestions on analyzing MD simulation data

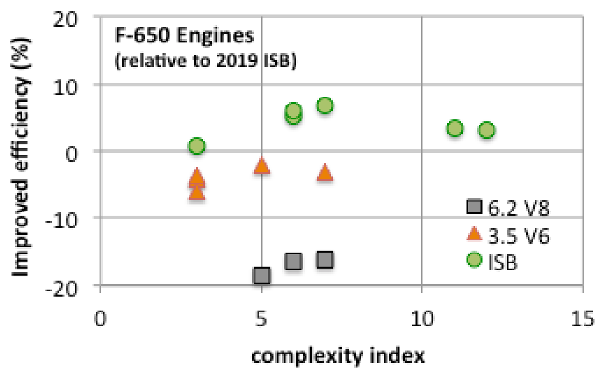
Results shown for WHVC – 50% load

F-650 Engine Technologies													
Package	Engine	Combustion	Turbochg	EGR	SCR	VVA	Cyl Deactiv	FMEP	Downspeed	Downsize	WHVC-rel	WHVC-net	Complexity
2013	ISB	-	base	base	base	none	-	-	2500	-	-3.8	-3.8	
2019	ISB	1%	base	base	base	none	-	5-17.5%	2500	-	0.7	0.7	3
6	ISB	1%	2.5%	base	base	none	-	5-17.5%	2200	-	6.7	6.7	7
7	ISB	1%	5.0%	None	high eff	none	-	10-35%	2200	-	3.2	3.2	12
8	ISB	1%	5.0%	None	high eff	none	-	5-17.5%	2200	-	3.5	3.5	11
9	ISB	1%	2.5%	base	base	none	-	10-35%	2500	-	5.3	5.3	6
10	ISB*	1%	base*	base*	base*	none	-	base*	3000	4 cyl	6.1	6.1	6
16	3.5 V6	stoich	base	base EGR	-	VVA	-	-	5500	-	8.8	-4.2	3
17	3.5 V6	stoich	base	base EGR	-	VVA	-	-	4000	-	11.0	-2.0	5
18	3.5 V6	Lean	base	base EGR	-	-	-	-	5500	-	7.0	-6.0	3
19	3.5 V6	stoich	base	base EGR	-	-	-	-	4000	-	9.4	-3.6	3
20	3.5 V6	GDI	base	base EGR	-	-	Cyl Deactiv	10%	5500	-	10.0	-3.0	7
21	6.2 V8	GDI	base	base EGR	-	VVA	Cyl Deactiv	10%	5500	-	7.8	-16.2	7
22	6.2 V8	GDI	base	base EGR	-	2-Phasers		10%	5500	-	7.7	-16.3	6
23	6.2 V8	GDI	base	base EGR		-	Cyl Deactiv	-	5500	-	5.4	-18.6	5

F650 MD Truck Technology Combination Results													
	Cd	Crr	Weight	AC power	Idle-N	Transm	ISB	3.5 V6	6.2 V8		WHVC		Complexity
	base	base	base	base	-	5-speed AT	0.0				0.0		0
11	15%	-			-	5-speed AT	2.5				2.5		1
11	-	30%			-	5-speed AT	6.8				6.8		2
12	-	20%				8-speed AT	6.5				6.5		4
		20%				8-speed AT		7.0			7.0		4
		20%				8-speed AT			6.2		6.2		4
13	-	20%			Idle-N	8-speed AT	7.7				7.7		5
		20%			Idle-N	8-speed AT		7.7			7.7		5
		20%			Idle-N	8-speed AT			6.7		6.7		5
14	-	20%				6-spd AMT	9.9				9.9		4
		20%				6-spd AMT		8.6			8.6		4
		20%				6-spd AMT			6.0		6.0		4
15	-	20%	700lb	40%	Idle-N	8-speed AT	11.0				11.0		8
	-	20%	700lb	40%	Idle-N	8-speed AT		11.0			11.0		8
	-	20%	700lb	40%	Idle-N	8-speed AT			9.4		9.4		8







Lowell

- The methodology used for this analysis was rigorous and appropriate for the aims of the project. It was also comprehensive enough to provide credible results.

- In general the methodology was clearly described, but there could have been more context provided for why some specific combinations of engine and/or vehicle technology were chosen. In many cases the logic is clear, in others it is not. For example, it is not completely clear why DD15 engine package 3b was chosen for vehicle technology package 4 (T700) or why DD15 engine package 5 was chosen for vehicle technology package 5 (T700) – as opposed to one of the other engine technology packages.

- The charge says that part of the purpose of this project was to evaluate the additive nature and synergistic relationships between different options for fuel economy improvement. To that end the authors did explore combinations of both engine and vehicle improvements for the T700 truck (vehicle technology packages 4 and 5). However, they did not do so for any of the other trucks; for the F650, T270, and Ram Pickup the vehicle technology packages included only the baseline engines – no packages included any of the modeled advanced engine packages. The reason why engine/vehicle synergies were only explored for the T700 and not the other trucks should be explained and justified.

Midlam-Moher

Weight was discussed specifically as a non-additive feature of some of the technologies used. Other than that, there was not a consistent and explicit discussion of if the technologies were additive or not. This could be done if the impact of individual technologies were assumed to be completely additive – one could then compare to the simulated results with the technologies deployed in a single simulation. Technology packages which outperformed the individual summation of technologies are synergistic, technology packages which did about the same are additive, technology packages which were much less interfere with each other. This could possibly be done on a 'meta' level looking at results from this study and that from Report #1.

Assumptions are often made and could be documented better. Once can search for the word 'assume' throughout and find many examples that could be better documented. For instance, source of assumption for "For 2019 baseline diesel engines, an assumption was made that there would be a 1% efficiency improvement due to combustion system development." in 2.1.1 – what is this assumption based on?

The vehicle simulation approach uses well-known simulation packages and is believed to be appropriate for the type of analysis conducted.

Regarding this: "Because WHR systems have very slow transient response, they do not contribute much useful work on highly transient cycles." I agree that the first half of the statement is accurate but not the second. If there is a cycle with a high average heat rejection that is transient a WHR system can still do well. I think this needs to be re-evaluated – assuming that a WHR system produces nothing on certain cycles is because they are 'transient' is not well supported by the report. It may be true, but it is a large assumption that is not backed up.

Regarding the GT-Power simulations, the details of this were presented and peer-reviewed in Report #1. I made a quick review of this but given that this was the subject of the Report #1 and there are little technical details in this report I am not providing specific comments.

The methodology section (2.2) could be enhanced some more with a particular focus on the approach used to validate the engine technologies. Many of the technologies simulated were extrapolations off of existing technology so a robust validation was not possible – that is quite relevant given the purpose of the report. Much of this was covered in Report #1 – but this should be emphasized here to provide good context for the work under review.

Nelson

General Comments. The methodology used by the authors, while not necessarily employing the identical modeling tools, is consistent with the work of other excellent published research (Ricardo, 2011; Muster, 2000) in terms of both model selection and application for the analysis of engine and vehicle technologies. The process used in the current report follows the sequence: 1) development of engine simulation model for known production engine; 2) prediction of effects of technology upgrades expected by a future date to establish new engine models to serve as more appropriate baselines; and, 3) insertion of the new engine baseline model(s) into vehicle simulations to predict total fuel consumption across a range of drive cycles. A key feature of this methodology, also commonly used, is that engine function is not adapted for anticipated decreases in levels of road loads. Additional comments are given in Question 2-2, regarding engine downsizing.

Use of a constant to express the tire coefficient of rolling resistance, Crr, is currently a widely accepted practice in vehicle simulations, even though the coefficient has weak dependence on vehicle speed and load in normal operating ranges (Laclair and Truemner, 2005). To be clear, the contribution of tire rolling resistance to *road load* (considered for practical purposes as a retarding force on the vehicle) is a linear function of total vehicle weight including payload under the constant Crr assumption. At some future point it may be of interest to incorporate tire rolling resistance road load as a function of vehicle load, vehicle speed, and tire pressure in simulation studies.

The authors have been thorough in their explanations of engine technologies, providing details of how each technology works, and the techniques for incorporating each technology into the simulations. Speaking as someone who has limited experience in engines and engine technology, I can only add that the simulation treatments are credible, and the level of elaboration of the technologies contributes significantly to the understanding of the results.

Two areas in which the report could be improved for clarity are the definition of engine/vehicle baselines and the treatment of technology interactions. Each area is discussed briefly for the example case of the DD15 diesel engine and T-700 vehicle.

Engine and Vehicle Baselines. References to the DD15 engine models contained in Report #1 and Report #3 include years 2011, 2012, 2013, 2014, 2017 and 2019. It is understood that the 2011 engine refers to the GT-POWER model developed from test cell data on a 2011 production year DD15, and that this serves as the baseline engine used in Report #1 for technology comparisons. The sequence of engine model updates from that point should be described in a single paragraph, including the technologies or strategies that were applied at each update to arrive at the 2019 baseline engine. It is unclear whether 2011 and 2012 refer to the same engine model, and similarly for versions 2013 and 2014, and whether any model other than that from the 2011 production year and the 2019 DD15 projected baseline was used in any simulations.

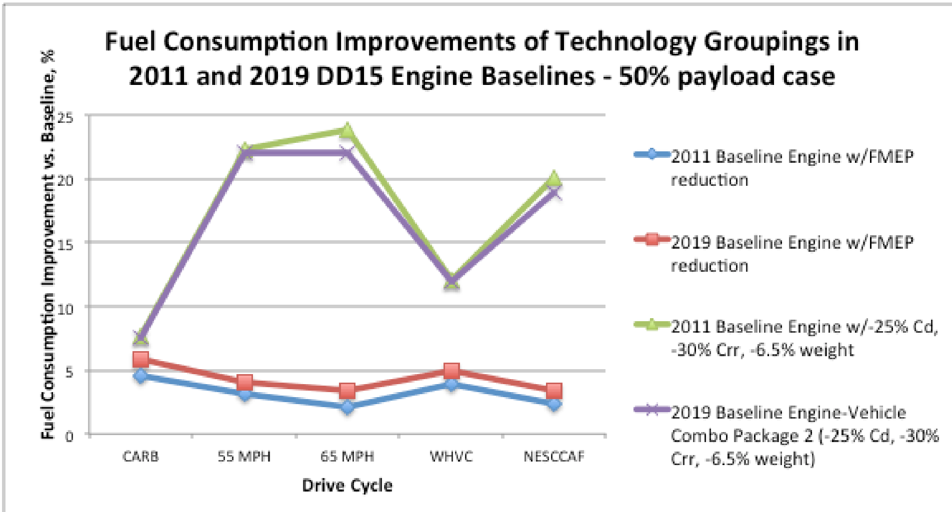
On the vehicle side, it should be clarified there are no differences made to the T-700 vehicle model during the course of the simulations other than replacement of the 2011 engine model with the 2019 baseline engine, e.g. no weight, aero, or tire improvements are assumed for the T-700 in going from the analysis of Report #1 to Report #3.

Interactions of Combined Technologies. Analysis of technology interactions has not been specifically presented in the report. For example, is fuel consumption due to a reduction in Crr affected by different levels of the coefficient of aerodynamic drag, Cd, on a given vehicle? Typically, we would say the answer is no, given the definitions of Crr and Cd embedded in the modeling. One way to explore additive effects on a very macro level would be to compare whether a technology, or package of technologies, provides the same level of fuel consumption improvement when applied to two different baselines.

The following graph shows the percent improvement in fuel consumption due to the same engine friction reduction (FMEP) for both the 2011 and 2019 baseline engines, across all drive cycles. The 2011 baseline DD15 + FMEP improvement (case #11 in Report #1) is compared to the 2011 baseline; likewise, the 2019 baseline DD15 + FMEP improvement (DD15 package #1 in Report #3) is compared to the 2019 baseline engine model.

Similarly, the combined effects of a 25% reduction in Cd, 30% reduction in tire rolling resistance, and 6.5% reduction in empty vehicle weight can be compared by adding the individual contributions to establish an improvement in fuel consumption versus the 2011 baseline (addition of cases II, JJ, and KK-6.5% from Report #1) compared to the T-700 Combined Engine-Vehicle package #2 in Report #3 which combines the same technologies with the 2019 baseline engine model.

These comparisons are shown below for the 50% payload case.



From these results, we would be likely to conclude that these technologies are largely additive, with small differences due to simulation uncertainties, modeling assumptions, or perhaps, real differences in interactions. The friction reduction cases show a consistently greater improvement when applied to the 2019 baseline versus the 2011 baseline engine. Vehicle weight, rolling resistance, and aerodynamic drag are expected to be additive if the baselines are similar enough, as the 2011 and 2019 DD15 models appear to be. More interesting cases could consider combined engine modifications and vehicle technologies, such as substituting the 2019 DD15 engine package 2 (downspeeding + partial FMEP reductions) into the T-700 combo package #2 (25% reduction in Cd, 30% reduction in tire rolling resistance, and 6.5% reduction in empty vehicle weight) to compare with an analogous 2011 package, which may show some evidence of interactions.

Nuszkowski

The quality, scope, and rigor were definitely there. The models were extensively calibrated with experimental data when available. Many combinations of engine and vehicle technologies were evaluated. The technologies chosen seem to be primarily additive and synergistic. What technologies were not additive? I believe this was explored by the author, but not included or discussed in the document.

The model was sufficiently described and is robust. The results will be best case scenarios since the methodology does not take into account transient effects, road grade, and different ambient conditions. These specific conditions are very important, but seem to be outside the scope of this project.

4.2-2 Were the technologies selected for the combinations appropriate, and were they logical pairings for the engines and vehicles simulated? If not, why not and what would you recommend?

Barth

Overall, the technologies selected were appropriate and logical for the vehicle. As mentioned above, it was difficult to determine how these combinations were selected in the first place; it seems that they were selected by NHTSA and SwRI in an ad-hoc fashion. Nevertheless, they seem appropriate. It would be interesting to see some combinations of the hybrid technology (e.g., integrated starter/generator) with the other standard FC savings measures.

de Ojeda

Yes, overall the combinations chosen are well thought out. There is no “formal” justification for the packages, but this is reasonable as there are informative discussions imbedded in each package results discussion.

Lowell

- The technologies selected for the different combinations that were analyzed were appropriate and logical.
- The charge says that part of the purpose of this project was to evaluate the additive nature and synergistic relationships between different options for fuel economy improvement. To that end the authors did explore combinations of both engine and vehicle improvements for the T700 truck (vehicle technology packages 4 and 5). However, they did not do so for any of the other trucks; for the F650, T270, and Ram Pickup the vehicle technology packages included only the baseline engines – no packages included any of the modeled advanced engine packages. The reason why engine/vehicle synergies were only explored for the T700 and not the other trucks should be explained and justified.

Midlam-Moher

The approach used to select the select the combinations is not clear. For instance, why is the “1% combustion efficiency improvement” and “FMEP reduction” not applied to vehicles with the bottoming cycle in the DD15 scenarios? I don’t see why these technologies would necessarily not work together. I realize that one can’t simulate every permutation but it is unclear what process was used. I would recommend clearly defining how these packages were arrived at.

This information could also be communicated more clearly than the tabular form used.

Nelson

General Comments. The current studies have benefitted greatly from well over a decade of continuous and concentrated research into medium- and heavy-duty truck fuel savings technologies summarized by the National Research Council (NRC, 2010 and 2014), the annual merit reviews of the four SuperTruck projects which are reaching the demonstrator phase (Jadin, 2012; Gibble and Amar, 2013; Koeberlein, 2014; Singh, 2014; Rotz and Ziegler, 2014; Delgado and Lutsey, 2014), the 21st Century Truck Partnership (2006), and other research such as an earlier study by MIT (Muster, 2000). Taken together, these programs have provided a generally consistent, progressive and widely reviewed foundation for the selection of fuel savings technologies.

In addition, the level of stakeholder involvement throughout the process is striking, encompassing OEMs and commercial truck equipment suppliers, research labs and universities, regulatory bodies, trucking industry representatives, fleet and maintenance managers, and drivers. Technologies have frequently received significant coverage in end-user literature (Berg, 2014; Brawner, 2015; Lockwood, 2015) and at industry meetings (TMC, 2015), promoting broad dialog in the industry about the advantages/disadvantages, costs, and implementation strategies of new trucking equipment.

Given this context, technology combinations for the T-700 are coherent with approaches reported by other researchers and by the SuperTruck projects, and represent combinations that are pertinent to fuel consumption evaluations.

Technology Selection and Pairings - 6x2 Axle Configuration and Tires. In one study of 6x2 versus 6x4 axle configurations (NACFE, 2014), a 6x2 “package” was identified as containing the following components: wide-base single drive tires on the drive axle, wide-base single trailer tires on the tag axle, “tall” axle ratio of around 2.6:1, use of low viscosity axle lubricant, and direct-drive transmission with down-speeding applied in some cases (approaching T-700 Combo Package 3, excluding aero and accessory power reduction). The NACFE study attributed fuel economy improvements in the range of 1.6% - 4.6% to the use of 6x2 axles, with various adjustments made to account for differences in the make-up of the tested vehicle packages.

A 6x2 axle can permit an overall reduction in tire rolling resistance on the vehicle if trailer tires are used on the tag axle instead of drive tires. An example shown in the following table using SmartWay thresholds for steer, drive and trailer tires indicates a 5% reduction in effective vehicle rolling resistance coefficient by substituting trailer tires on the tag axle, e.g. from a value of Crr(veh) of 5.95 kg/T to 5.63 kg/T. The effective vehicle Crr(veh) is given as:

$$Crr(veh) = [\ \Sigma_j\ Crrj * Zj] \ /\ [\ \Sigma_j\ Zj\ ]$$

where, Crrj is the coefficient of rolling resistance for tires on axle j, and Zj is the total load on that axle. The rolling resistance decrease is considered as an enabled tire contribution to vehicle fuel consumption improvements.

Description	Steer Axle Weight, lb	6x4 Drive Tandem or 6x2 Drive Axle Weight, lb	6x2 Tag Axle Weight, lb	Trailer Tandem Weight, lb
100% Payload case, Total vehicle weight 80000 lb., 6x4				
Load distribution of 46040-lb payload tractor-trailer	**12000**	**34000**	**n/a**	**34000**
% weight carried by axle or tandem	**15%**	**43%**	**n/a**	**43%**
Jan 2015 SmartWay thresholds for Crr tires, kg/T (ISO 25850)	**6.5**	**6.6**	**n/a**	**5.1**
Rolling resistance contribution of axle to Crr(veh), kg/T	**0.98**	**2.81**	**n/a**	**2.17**
Total effective vehicle rolling resistance coefficient, Crr(veh), kg/T	**5.95**			
% Contribution of axle, tandem to total effective vehicle Crr(veh)	**16%**	**47%**	**n/a**	**36%**
100% Payload case, Total vehicle weight 80000 lb., 6x2				
Load distribution of 46040-lb payload tractor-trailer	**12000**	**17000**	**17000**	**34000**
% weight carried by axle or tandem	**15%**	**21%**	**21%**	**43%**
Jan 2015 SmartWay thresholds for Crr tires, kg/T (ISO 25850)	**6.5**	**6.6**	**5.1**	**5.1**
Rolling resistance contribution of axle to Crr(veh), kg/T	**0.98**	**1.40**	**1.08**	**2.17**
Total effective vehicle rolling resistance coefficient, Crr(veh), kg/T	**5.63**			
% Contribution of axle, tandem to total effective vehicle Crr(veh)	**17%**	**25%**	**19%**	**39%**

The NACFE study included some preliminary data indicating that the 6x2 configuration can decrease the wear life of the tires on the drive axle by approximately 1/3, potentially requiring more frequent replacement of tires on this axle. It should be noted that under normal operations trailer tires (on a trailer axle) are likely to have half the wear life of drive tires on a 6x4 configuration (Michelin, 2011). This suggests that trailer tires on the 6x2 tag axle would also need to be replaced more often than drive tires on a 6x4 axle configuration. Effectively, this suggests that tires on both drive and tag 6x2 axles would need to be changed out more often than tires on the drive tandem of a standard 6x4 truck.

This aspect of 6x2 configurations will need to be considered when calculating tire life cycle costs. It should be further noted that heavy-duty truck tires have a non-zero residual value due to the casing which can be retreaded several times. This tire residual value was not reported in the cost analysis of Report #2 (Tetra Tech draft cost study).

Certain new 6x2 products are being developed with the capability to shift load from the tag axle to the drive axle to improve traction. Under this operation, assurance of sufficient tire inflation pressure to support the increased load is critical, as loading can exceed the standard level of 17,000-lb per axle. Wheels must also be able to support the maximum loading.

Aerodynamic Fitments and Tires. Report #3 does not stipulate specific aerodynamic treatments or equipment, but it would not be unusual for a future truck to deploy side skirting which covers both the drive and trailer tandem axles, potentially cutting off convective tire cooling. Airflow around the wheel ends will need to be managed to ensure that tires, wheels, and braking systems are all adequately cooled if isolated from normal ambient airflows.

Engine Downsizing and Reduced Road Load. Engine downsizing is a technology that was not carried over into the combined technologies study. However, combinations of road load reductions can enable engine downspeeding and downsizing in commercial vehicles. This approach has been described in both Daimler and Volvo SuperTruck projects (Delgado and Lutsey, 2014) and has been used in the most recently displayed Daimler SuperTruck demonstrator (McNabb, 2015). An estimated reduction in road load power demand may shift the engine operation to a zone of lower efficiency on the fuel map, which is then compensated for by engine downspeeding and downsizing.

Nuszkowski

The technologies selected were logical combinations and pairings.

4.2-3 Were the vehicles and drive cycles used in the study appropriate within the context of evaluating Class 2b-8 fuel consumption performance?

Barth

Yes, the vehicles and drive cycles were appropriate for this class of vehicles (see earlier comment about driving cycles).

de Ojeda

Yes, the cycles are appropriately chosen for each vehicle configuration.

- The cycles selected allow an understanding of how different engine and vehicle technology combinations perform across a range of applications through the drive cycle selection. The study considers too sensitivity to payload. The choice of 3 payloads provides sufficient resolution for weight impact.

- The HD, MD T270 and F-650, and the Ram Pickup engine and vehicles use a different set of cycles given the nature of the application. He process is well thought out as shown in the Ram Pickup cycles. This category accounted for an empty truck, 50% of the maximum payload in the cargo bed (8,500 lbs) but no trailer (ALVW), and with trailer (25,000 lbs). The latter case accounts for the frontal area increased by 50% to account for the aerodynamic drag of the trailer.

Items that are unclear to this reviewer:

- The choice of multiple WHR options seems disproportionate (e.g. multiple fluids). Overall 7 iterations are presented out of 11. They all point to the same conclusion (high efficiency). The discussion needs to consider the impact of fluids from the perspective of safety (EtOH, MeOH are highly flammable, water will have to cope with freezing).

- On the other hand, only one turbocompounding option is presented.

Lowell

- Yes, the vehicles and drive cycles used in this study were appropriate to the task of evaluating Class 2b-8 fuel consumption performance.

- The only way in which the chosen vehicles and drive cycles do not adequately cover the full range of Class 2b-8 vehicles is that they do not address vocational vehicles with significant engine-driven vocational loads – for example refuse trucks (hydraulic packer), cement mixers, utility trucks (aerials), etc. That being said, these vehicles likely represent a very small percentage of total fleet-wide fuel use, so incomplete coverage of these vehicles in this project will not significantly reduce the value of the results.

Midlam-Moher

I believe that that vehicles were representative. This could be backed up further with fleet data demonstrating the prevalence of these classes of vehicles in the US fleet.

I believe that the drive cycles were appropriate.

Nelson

Classes 2b, 6, and 8 commercial vehicles have historically represented the combination of the greatest number of commercial vehicle classes on the road and those which consume the most fuel. Ninety percent of the fuel consumed by all medium- and heavy-duty trucks can be attributed to these classes (NRC, 2014). This characteristic, together with the vehicle selection process described in Report #1, support the decisions to include the Ram pickup, T-270 straight truck, and T-700 Class 8 tractor in the study. Given that data was available to support analysis of the Ford F-650, and that the vocational sector has perhaps been under-represented in fuel consumption studies to date, makes this vehicle a useful addition to the project.

Across all vehicles, including light-duty, tire rolling resistance is estimated to account for 8%-18% of the total fuel energy consumption (engine losses being 50% or greater). The amount of fuel savings due to reductions in rolling resistance can vary as much from vehicle to vehicle as from drive cycle to drive cycle. Estimated sensitivities are reported to range from 10:0.5 to 10:1 in light duty vehicles to 10:1 to 10:3 for medium- to heavy-duty vehicles (Hall and Moreland, 2001). A ratio of 10:3 would be interpreted as a 10% reduction in tire rolling resistance coefficient generating a 3% reduction in fuel consumed, which is a return ratio that approximates Class 8 tractor-trailer sensitivity.

Because of differences in fuel consumed due to rolling resistance for different drive cycles, it is important that each vehicle in the study be subjected to multiple cycles, covering a wide range of operations for a vehicle type. It is unlikely that a single drive cycle can coherently represent vehicle usage. The drive cycles used in the study are familiar and widely used, and, taken as a package for each vehicle type, cover many truck applications. The key decision will be how to combine all or some of the drive cycles to represent the overall usage of each type of vehicle. One approach is to use weighted combinations of fuel consumption from some or all of the cycles studied for a given vehicle category, the values of the various weighting factors being the crucial choice. Alternatively, individual performance targets could be set for each vehicle class for one or more individual drive cycle(s).

Nuszkowski

The vehicles and drive cycles used were appropriate to get a wide breadth of fuel consumption performance. The vocational worksite trucks drive cycles are still the hardest to quantify. The difficulty of quantifying overall fuel consumption reductions for this vehicle type was addressed through discussion.

4.2-4 Were the computer models chosen appropriate for the analysis, and were they applied correctly to model vehicle and engine technology performance?

Barth

Yes, the computer models were appropriate for the analysis. Although many assumptions were made, they all seemed logical. The modeling results provided reasonable numbers and are very good for relative comparisons.

de Ojeda

The GT-POWER tools used are proven and widely used in the industry for engine modeling. The base models are calibrated with experimental data. The authors do a very nice job to include test heat release data, actual turbocharger maps (or scaled maps). EGR and AFR are controlled to match the baseline engine. The Appendices give comprehensive maps of the more important modeling parameters, including well resolved maps of the fuel consumption. Vehicles and vehicle technologies were modeled using SwRI's Vehicle Simulator, a proven tool. The Vehicle Simulator tool can handle the range of vehicle technologies studied here.

For clarity as a stand along publication, Report 3 may want to include the definition of the term "Fuel Savings" (as was done in Report 1).

Lowell

This is not my area of expertise, but given my limited knowledge it appears that the computer models chosen were appropriate to the task and applied correctly. I believe that there is adequate description and discussion of the models, their limitations, and the assumptions used, for informed readers o make appropriate judgements about the accuracy and utility of the results.

Midlam-Moher

The vehicle models were appropriate.

The engine modeling approach was appropriate and good judgment was used in accommodating for the weaknesses is this type of tool. (See previous comment about enhancing the discussion on validation of models.)

For the WHR system, see earlier comment regarding transient modeling.

Nelson

The computer models chosen for engine/vehicle simulations, and the overall modeling approach, are similar to those typically used by other researchers (Laclair and Truemner, 2005; Gibble and Amar, 2013; Ricardo, 2011; Muster, 2000). One notable difference between researchers is whether a driver model is incorporated in drive cycle simulations; an evaluation of this difference is outside my area of expertise.

Nuszkowski

The computer models chosen were appropriate for the analysis. GT-Power is an industry accepted and widely utilized software. The background and validation of the in-house vehicle modeling tool developed by Southwest Research Institute (SwRI) was included in Report #1.

4.2-5 Are the assumptions used in the analysis reasonable? Why or why not?

Barth

Yes, the assumptions are all reasonable.

de Ojeda

Yes. The report does a good job indicating the assumptions used and their rational. Some examples include:

- Good description of the pumping work and its role in engine efficiency,
- The distinction between FMEP (cylinder kit, bearing, valve train friction, fuel, oil, and water pumps, piston cooling nozzle) and accessory (not essential to engine operation such as AC compressor, alternator, power steering pump, air compressor, and engine cooling fan),
- When presenting vehicle package P4, containing the DD15 P3b with WHR, the report is cautious to not add weight reduction,
- The report notes the challenge of adapting existing SCR units on lean burn gasoline engine to reduce NOx owing to the large exhaust temperatures,
- The modeling takes into account Idle-neutral features and the characteristics of the larger geared automatic s and the AMT transmissions. These are well documented in the Appendix.

Clarifications needed:

- Page 34, Engine Technology for the T270, “The same engine technology combinations have been evaluated in two different medium duty vocational trucks” seems redundant given the previous statement before it and it reads like there is two T270 trucks under study.
- Page 37-38. The comparison between the T270and F-650 is very useful. The discussion on the ISB is very clear, but no so with the V6 and V8 engines. The text regarding the rich-operation (it is stated to be more efficient) is not expected.
- There is a potential source of confusion in the results for the **MD Vocational Truck and the Pickup Truck Engine and Vehicle Technology Combinations**. Results are shown in terms of <u>percent fuel consumption reduction compared to each engine’s baseline projected 2019 configuration</u>.
    - o In addition to the benchmarks provided, **results would be more useful if expressed in % fuel savings with respect to one common reference.** This is done only briefly in the conclusion for a brief sample of the cases considered. *The report does addresses the differences between baseline engines, such as in Figure 2.7. The dependence on cycles is shown at 50% payload. Here shows that the V6 gains approximately 11% (varies with cycle) and the ISB gains approximately 24% (varies with cycle) over the V8 baseline.*
    - o The report uses the “ISB 2019” as baseline for the technology comparison. This effectively means that the V6 entries (P16-P19) and V8 entries (P20-P24) have a 13% and 24% fuel deficit respectively. *The*

report does indicate that Diesel has a 13% fuel consumption advantage over the gasoline engine due to the energy differences for the same volume.

  - Overall, comparing to one same reference would add clarity.
  - Costs, durability, need be considered such as with an efficiency vs. cost tradeoff.

- ISB package 10 is difficult to follow. The downsizing, remake of the lug line of the engine, and the vehicle axle ratio modifications makes this entry significantly different than the others. This same package retains EGR.
- Same ISB package 10 could have considered SCR.

Lowell

Yes, the assumptions used in the analysis are reasonable.

Midlam-Moher

There were no assumptions that I found to be unreasonable. However, there are many assumptions that are not referenced to any sort of supporting material. For the majority of these assumptions there exist publications that could be easily references to support the assumed value. I think this should be done in this document – otherwise it is unclear to the public that this number is valid.

Nelson

Typical simulation studies assume the tire rolling resistance coefficient, Crr, to be constant across different levels of payload and different speeds, given that the dependence of Crr on load and speed is relatively weak in the normal range of truck operating conditions. Use of a constant coefficient greatly simplifies calculations and sensitivity studies while generally providing satisfactory results.

Tire rolling resistance is a function of load, inflation pressure, speed, applied torque and steer angle, as well as tire temperature, camber, and the wheel used. Moreover, the tire operating temperature, a highly influential parameter for tire pressure, depends on the history of the conditions under which the tire has operated (Laclair, 2005). One approach to determine transient tire rolling losses is to use data from a coastdown machine test to solve for the coefficients in the following equation (Laclair, 2005; Hall and Moreland, 2001):

$$Fr = (P^{\alpha})(Z^{\beta})\,(a + bV + cV^{2})$$

In which:

Fr = tire rolling loss

P = tire internal pressure

Z = vehicle weight carried on the tire

V = speed

a, b, c, α, β = fitted coefficients.

To date the current test method, SAE J2452, has been specified for passenger car and light-truck tires only.

In actual field usage, the tire warms and cools according to operating conditions, altering the internal pressure which in turn dictates actual rolling resistance at any given moment. Predicting tire rolling resistance during the course of a transient drive cycle can be a challenge. On a Class 8 tractor-trailer using steer, drive, and trailer tires, the operating conditions for each tire type are different for each axle. In terms of fuel consumption, a more complex tire rolling resistance model may not offer any improvements in prediction over models based on constant Crr. I am not aware of any studies comparing the use of constant Crr to represent rolling resistance versus the above equation in order to calculate fuel consumption for commercial trucks.

Nuszkowski

There were many assumptions applied during the study and they seem reasonable.

4.2-6 Are the findings and conclusions adequately supported by the data? Describe any findings or conclusions that are not sufficiently supported. Describe any ways in which this section could be improved, as well as any additional key published data relevant to this review that should be included.

Barth

In general, the conclusions are adequately supported by the data. However, this section needs a good wrap-up set of paragraphs that talks about the different results at a higher level. For example, how did all of the technology combinations compare across different vehicle platforms? What might be other technology combinations that were not explored? (e.g., the inclusion of mild hybridization with other standard FC saving technology).

de Ojeda

Yes. The findings are highly coupled to the simulation work performed.

- The report does a good job to tie in the work and performance results from the Supertruck program when considering the more technologically aggressive packages on the T700 vehicle.
- There are some very good insights in the report that may not be readily known:
    - The downspeed option (ISBP 6 and ISB P8) show a slight and rather large fuel penalty on the CARB and Parcel drive cycles. The report indicates that the higher torques at lower rated speeds will require tighter torque match to reduce the fuel requirement when vehicle is stationary.
- This reviewer found the comparison section *2.3.7.1 Comparison of engine technology results between the T270 and F-650* particularly useful as it provided a good summary of the technologies and how they related to the results found in the report.

Suggestions:

- The "state-of-the market" discussion on *2.3.11 Hybrid System Results* is brief but informative. The results of the simulation (performed by Argonne) is shown. Further discussion may place these results in the context of the engine and vehicle: asses at least qualitatively if not quantitatively the efficiency vs. cost/complexity that this option provides; highlight barriers to overcome the poor payback and the technical challenges to migrate the technology to the MD-HD sector.

Clarifications needed:

- In section 2.3.2.12 DD15 Technology Package 5: Packaging the reduced restriction intake, exhaust, and charge air cooler systems in a practical vehicle would prove very difficult. Please explain why.

Lowell

- The findings and conclusions of this section are adequately supported by the data
- This section could be improved in the following ways. These suggestions are primarily designed to improve the readability of the report and to help the reader more easily understand the interconnections and implications of the data presented:
  - In section 2.2, pages 10 – 11, when discussing the different drive cycles used in the analysis, for each drive cycle the authors should indicate the relative amount of engine load imposed by the cycle (low to high). In Table 2.10 the individual drive cycles should be listed in order of low to high engine load from left to right.
  - For all of the tables and figures in Section 2, the results should be consistently shown with the different drive cycles in order of low to high engine load from left to right – i.e. for Figure 2.1 the order from left to right should be WHVC, CARB, 55 MPH, 65 MPH, NESCCAF, rather than the order in the existing figures. This would allow the reader to more easily see the relationship between the fuel economy results and the relative severity (engine load) of the duty cycle, which for many of the technologies appears to be fairly consistent.
  - For all of the tables and figures in Section 2, in addition to results for the individual drive cycles the authors should also show results for a weighted average of the CARB, 55 MPH, and 65 MPH cycles, as currently used in GEM for certification under NHTSA/EPA Phase 1. This would more easily allow the reader to put these results into the context of existing regulations and therefore judge how they might apply to future regulations.
  - In tables 2.2, 2.3, 2.4, and 2.5, for the description of the engine and vehicle technology packages the authors are not consistent in how they number each package, which is confusing. For example, in Table 2.2 which describes engine packages for the ISB medium-duty engine the notes for Package 9 say: "Compare to package 1", but Package 1 is not an engine package for the ISB medium-duty engine, it is an engine package for the DD15 heavy-duty engine (Table 2.1). For Package 9 the note should say "Compare to Package 6" (the first package for the ISB engine in Table 2.2). There are numerous other similar examples that should be corrected because it is confusing as written.
  - For all tables in this section, every number in a given table should be shown with the same number of significant digits (i.e. if numbers less than 10 are shown with one significant digit (2.0) then numbers greater than 10 should be shown with one significant digit as well (10.0, not 10)
  - In Section 2.3.2.10 there appears to be a mistake. The text says: "The overall fuel savings performance of the P3f system is similar to that of the P3d <u>Ethanol</u> + recuperator system." I believe that this sentence should say "The overall fuel savings performance of the P3f system is similar to that of P3d <u>Methanol</u>, + recuperator system".
  - The fact that this section directly compares in the same tables and figures the "Fuel Savings %" for different configurations of diesel and gasoline engines, with Fuel Savings denoted in gallons, is somewhat mis-leading to the reader. The text does note the fact that diesel has 13% more energy per gallon than gasoline, but it is hard for the reader to translate this information so as to compare the gasoline and diesel engine options on an energy equivalent basis. In addition to the existing tables and charts, the report should include figures which directly compare the modeled gasoline and diesel engine options on an energy-equivalent basis. There are several option for doing this, all of which would be essentially equivalent; one could plot the % reduction in btu/mi or btu/cycle, or one could

plot the % reduction in gasoline-gallon equivalents (GGE) per mile or GGE/cycle. Alternatively, one could plot the % reduction in carbon dioxide (CO_2) emissions per mile or per cycle. This option would be appropriate given that this report is in support of joint NHTSA/EPA rulemaking that will set fuel economy and GHG emission standards. At a minimum this information should be added to sections 2.3.5.16, 2.3.7.1, and 2.3.9.17.

- It is hard for the reader to evaluate whether the range of aerodynamic drag and rolling resistance reductions included in the T700 vehicle packages (15%, 25% C_d reduction; 10%, 30% C_{rr} reduction) was reasonable, because there is no discussion in the document of what types of changes might be required to the baseline truck in order to achieve this level of reduction. For example, photos of the Kenworth T700 show that it has a very aerodynamic shape. What changes to the T700 cab and/or standard trailer would be required to reduce the combined C_d by 25%? What specific model of tire was assumed for the baseline T700 and why? Are there commercially available tires for this truck that would reduce C_{rr} by 30% compared to the baseline tire? Providing this information, along with a photo of the baseline truck and trailer that was modeled, would allow the reader to better put the data in this report into the proper context.

Midlam-Moher

I feel that the findings are supported by the data. The key to a simulation like this is to have well-vetted input data to the simulation. Most of the input data for this simulation was presented in Report #1. I feel the process used here is straightforward (although very technical and time consuming to execute…) and that the inputs are really what is driving the results.

I feel that this section would benefit from a ‘summary of the summaries” so to speak. Right now there is a tremendous number of tables and figures showing data. At the end of the section, it would be powerful to somehow do a weighted average (or just straight average) of the different cycles and provide a few simplified figures. Another suggestion might be reporting on the min/mean/max/std of the technologies deployed to give an idea of how much variation there is. This would also facilitate comparing between the classes of vehicles. It might also be helpful to pull out technology packages that were identical (or similar) across vehicle classes to show how they change across class.

I have no other specific recommendation other than those that were included above.

Nelson

Technology Interactions. Although occasional comments on the potential additive nature of certain technology groupings are made in the report, this topic has not yet received in-depth treatment. Identification of interactions is one of the primary objectives of the study, and would make a good concluding section for the chapter.

Out-of-Scope Technologies. A brief listing of out-of-scope technologies, such as start-stop, driver habits, active tire pressure controls, continuously variable transmissions, and route optimization can be beneficial for the reader, and also set the stage for future research.

References. The following report discusses differences and similarities between light-duty and heavier pickups and vans, including fuel savings technologies, market and use patterns, and current GHG and fuel consumption standards.

Lutsey, N., "Regulatory Considerations for Advancing Commercial Pickup and Van Efficiency Technology in the United States", The International Council on Clean Transportation, April 2015, http://www.theicct.org/sites/default/files/publications/ICCT_pickup-van-efficiency_20150417.pdf.

Nuszkowski

The findings and conclusions are supported.

The hybrid system results were not discussed and the table wasn't referenced. The text in the hybrid section did not flow with the rest of the document. The table was organized differently and had different significant figures than the rest of the document. This section needs to be cleaned up.

4.3 Vehicle Parameter Sweeps

4.3-1 Please comment on Section 3. The purpose of the parameter sweeps was to gain an insight into the sensitivity of vehicle fuel consumption to the various parameters considered. Were the parameters chosen for the simulation sweeps realistic for the medium-duty vehicle segment?

Barth

- I'm not sure why Figure 3.1 only shows the Cd values of 5% and 10%, where the other figures showed 5%, 10%, and 15%. Why was 15% left out?
- The general conclusions of aerodynamics are logical, the main effect occurs at higher and sustained speeds.
- On page 62, the sentence "The large frontal area of the T270 limits the portion of road load that comes from tire rolling resistance" needs more explanation… how does the frontal area limit the rolling resistance road load?
- For rolling resistance reductions, it should be mentioned that there might be other important less desirable implications such as lower traction, load distribution, etc.
- For the weight reduction, it is unclear how the different weight reduction values were chosen for the different vehicle types. The RAM pickup was studied at 300, 600, and 900 lbs. The F-650 was studied at 400, 700, and 1000 lbs. The T-270 was studied at 400, 800, 1200 lbs. Were these chosen based on a general percentage of the vehicle's overall weight?
- The section of axle ratios provides a good explanation of the strong tradeoff between fuel economy and torque required for heavy loads. It seems that torque performance requirements have to be met first, then adjusted for best fuel economy.
- It seems that the section on axle ratios (sections 3.4, 3.5, 3.6) has a lot more detail than the other parameters sensitivity analyses; although it is interesting, I'm not sure if it adds a lot to the report. As mentioned, you design a vehicle to meet certain performance specifications, and then you do what you can get improved fuel economy without affecting those performance specifications.

de Ojeda

The study selects aerodynamic drag coefficient (Cd), tire rolling resistance coefficient (Crr), axle ratio and vehicle empty weight as the parameters for study. This section focuses on single parameter sweeps, unlike the earlier section that focuses on combination technology packages. These parameters are important for the MD vehicle performance.

Section 3 could be enhanced by:

- Indicating that the results in Sect 3.1 (aerodynamic sweep) may be referenced to Section 2. The results for Fig 3.1 were presented in page 52 for P16, for Fig 3.2 in page 29 for P11, and for Fig 3.3 in page 39 for P6.
- Improve consistency in the report: Package P16 is noted in Fig 3.1, but P11 and P6 are not in the following Fig 3.2 and 3.3.
- Improve consistency in the report: Table 3.1 lists the max percent grade in top gear, even when downshifted take place. The following Tables 3.2, 3.3 don't. Similarly Table 3.2 shows Gear Bound entries, but Table 3.3 does not (ISB 6.89 AR entry).
- Providing a summary on the overall contribution of aero, rolling resistance, AR and weight that compare one with respect to the others.

Typos and possible corrections:

- Page 59-63. The results for **Cd and Crr sweeps** as shown in the figures appear to scale (the relative size of the Fuel Savings bars are same across cycles as the sweep takes place). This seems to imply that Cd or Crr impacts on vehicle drag and friction does not change across drive cycles (but these have wide ranges of speeds and accelerations). Could these results be checked?
- Page 62. On the F-650 and T270 trucks, the largest fuel savings comes at 55 MPH, with the second largest benefit at 65 MPH (figures show it is WHC instead – though most cycles are relative same with exception of the Parcel).
- Page 65 Fig 3.10, title Ram P2 (should it be P17).

Lowell

Yes, the parameters chosen for the sweeps represent a realistic and comprehensive range of vehicle characteristics that could affect fuel use for medium-duty vehicles.

Midlam-Moher

Yes, this the selection covers the main factors at the vehicle level.

Nelson

Across the discussions of vehicles, engines, and drive cycles in this section, frequent reference is made to the relative importance of one component of road load versus another on a case-by-case basis. Given that there are generalizations that can be made concerning aerodynamic drag, tire rolling resistance, and vehicle lightweighting, it is recommended that an additional report section be included which presents the classical equations for each of these components. The material could be included at the beginning of Section 3.0 or in an appendix, and would make evident the relationships of:

- Aerodynamic drag force as a function of velocity squared, coefficient of aerodynamic drag, and vehicle cross-sectional area exposed to wind;
- Vehicle inertial forces as a function of vehicle mass and acceleration;

- Tire rolling resistance forces as a function of vehicle mass and the tire coefficient of rolling resistance.

This would make more intuitive the effects of vehicle weight reductions (affecting the road load contributions of both vehicle inertia and tire rolling resistance), drive cycle average speed and speed variability (impacts of aerodynamic drag and inertial effects), and additive improvements due to Cd and Crr (linear relation between the coefficients and road load, and, on the face of it, no interactions between the two coefficients since they do not share any underlying factors in their equations). Fuel consumption sensitivities could be more readily inferred, even for vehicles not subjected to simulation studies, knowing that, for example:

- Fuel consumption of vehicles with greater projected frontal area has greater sensitivity to changes in Cd;
- Fuel consumption of heavier vehicles is more sensitive to changes in Crr;
- Steady-state drive cycles have low sensitivity to lightweighting.

An example of a diagram that can be useful for explaining the relative magnitudes of the road load components during the course of a drive cycle can be found in Figures 29 and 30 of Muster, 2000, illustrated for a highway driving cycle. Similar graphs could be developed for selected cases in Report #3. This visual aide may illustrate more readily and broadly the conclusions of Section 3.1.

Nuszkowski

The parameters of drag coefficient, rolling resistance, vehicle empty weight, and axle ratio were realistic. Why was this only done for the medium-duty vehicle segment? The results from the KW T700 were not shown, but the parameters were included in the appendix.

4.3-2 Were the ranges used for each parameter in the sweeps appropriate?

Barth

Yes, the ranges are appropriate for all 4 different paramters

de Ojeda

The ranges are appropriate.

Suggestions:

- The report could gain if it provided a short description on what features would be responsible for the magnitude of the sweeps. For example, Cd% reduction range per each vehicle category (roof deflectors, fuel tank fairings, box skirts, mirrors). Same could be done for Crr% reduction. Maybe a reference could be inserted here such as ***Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles (National Academies Press, Jul 30, 2010).*** Similarly, a justification for the weight reduction quantities can be given.

- The results presented under the Ram Axle Ratio Sweep, when comparing the engine configurations, adjusts the gasoline engine axle ratios to a shorter setting (higher AR value) to match the towing capability. However, the figures in the section represent simulations at ALVW (much lower load). *This may be okay as tater in the section, the study takes up the effect of AR on grade performance, and here the effect of AR is seen at the higher payload - GCW.*

Lowell

- For aerodynamic drag it is difficult for the reader to evaluate whether the range used in the sweeps was appropriate because there is no discussion in the document of what types of changes might be required to the baseline trucks that were modeled in order to achieve this level of reduction. For example, photos of the Kenworth T270 show that it has a somewhat aerodynamic shape, but not as aerodynamic as the Kenworth T700, for example. Would changes to the T270 cab to make it look like the T700 cab reduce C_d by 10%? What more would be required to reduce C_d by 20% or 30% (i.e. rounded top and corners for box body, roof fairing between top of cab and top of box, side fairing between side of cab and side of box, other?). Photos of the baseline vehicles, and discussions of the types of changes required to achieve 10%, 20%, and 30% reduction in C_d would be very helpful to the reader to put the results of the aerodynamic sweeps into the proper context.
- For rolling resistance it is difficult for the reader to evaluate whether the range used in the sweeps was appropriate because there is no discussion in the document of what types of changes might be required to the baseline trucks that were modeled in order to achieve this level of reduction. For example, what specific model of tire was assumed for the baseline trucks and why? Are there currently commercially available tires for these specific vehicles that would reduce rolling resistance compared to the baseline tire by 10%, 20%, and 30%? Including this type of discussion in the document would be very helpful to the reader to put the results of the rolling resistance sweeps into the proper context.
- The ranges for the weight and axle ratio sweeps are appropriate.

Midlam-Moher

Yes – however – there should be citations demonstrating that the chosen ranges are span what is believed to be technically achievable over the relevant time period.

Nelson

Tire Rolling Resistance Coefficient. Whether the projected reductions in tire rolling resistance coefficient are appropriate depends on what is considered as the baseline Crr value for each vehicle, and whether that value represents a sales-weighted average tire or a best-in-class tire. However, the linear relationship between percent change in Crr versus percent change in fuel consumption can be used to evaluate the impact of potential tire improvements, even if machine measured Crr values are not exactly represented. For pickup trucks, Crr reductions summarized in Lutsey (2015) suggest that 10%-20% reduction is a reasonable working range.

Class 8 tractor-trailers may present more opportunities for rolling resistance reductions than the other study vehicles since the Class 8 vehicle is equipped with several different tire types – steer, drive, and trailer – with each tire type optimized to the operating conditions of its specific axle position. Class 8 enabling technologies, such as the use of 6x2 axle configurations, can permit the vehicle to be fitted with an overall lower Crr tire set. The Ram pickup, F-650, and T-270 use the same tire fitments in all wheel positions, so improvement options are more likely to be limited to direct reductions in Crr.

Aerodynamic Drag/Weight Reductions. Lutsey also reports opportunities for improvements of 10-20% in Cd and also in vehicle weight reductions, based on light-duty simulations. Industry publications indicate Cd ranges of approximately 0.4 – 0.42 for the 2009 model year of this class of pickup truck (Witzenberg, 2009), and Cd ranges of 0.36 – 0.41 for 2015 model years (Sanchez, 2014). The latest Ford F-150 EcoBoost includes a 700-lb weight reduction, or approximately 12-14% of the empty vehicle weight. These values, although not in the same vehicle class, support the range of Cd and weight reduction percentages considered in Report #3.

Nuszkowski

The ranges were appropriate.

4.3-3 Were the vehicles and engines used in the parameters sweeps appropriate?

Barth

Yes.

de Ojeda

Yes, the vehicles and engines chose were appropriate.

Lowell

Yes, the vehicles and engines used in the parameter sweeps were appropriate.

Midlam-Moher

Yes.

Nelson

This combination of vehicles and engines represents an opportunity to compare potential interactions between engine types and each of the three primary road load components. As the weights of the F-650 and T-270 are relatively close in this exercise, it is not surprising that the two vehicles show very similar sensitivities for Crr and lightweighting sweeps.

For the cases presented, there are small differences in engine sensitivity to lightweighting. It would have been interesting to see if more significant differences in sensitivity across the three engine types are observed when paired with Crr reductions.

Nuszkowski

The vehicles and engines used were appropriate.

4.3-4 Are the results plausible and well supported?

Barth

Yes, the results are plausible.

de Ojeda

The results are reasonable. The methodology used in the simulation follows the same approach as in Section 2. Results are well organized and discussed.

Section 3 highlights or re-emphasizes what may be an important question for future regulations:

- The fuel economy gains for individual technologies are very dependent on the drive cycles.
- How can the regulatory body and manufacturers work to better align regulatory cycles to real-world applications and thus encourage technology packages such as the ones discussed in the Report?

Lowell

Yes, the results of the parameter sweeps are plausible.

Midlam-Moher

The majority of the simulation results show consistent and the expected trends. There are a few (see Figure 3.18) that are demonstrate some unusual behaviors. The simulations to do this are fairly straightforward, so it should be easy to isolate and describe why the behavior of these cases (e.g. CILCC below) is so strange. Overall there is great detail on the vehicle/engine models – but something like an inappropriate shift schedule could lead to this type of unusual behavior.

It could be that there is a good explanation of these behaviors – but without that being discussed sufficiently it casts some doubt onto the approach.

Nelson

The rolling resistance results for all three vehicles – Ram pickup, F-650, and T-270 - are within the ranges of vehicle sensitivities as a function of weight class discussed in the response to Question 2-3.

Nuszkowski

The results are plausible.

4.4 Vocational Truck Fuel Consumption and Performance

4.4-1 Please comment on Section 4. The purpose of the analysis in this section was to explore the effect of vehicle specifications (explored in Section 3) on vocational truck fuel consumption and performance, as well as to consider the potential for a market shift towards gasoline power in the vocational segment. Are the discussions accurate and relevant to the subject matter?

Barth

- Section 4 is an interesting section, describing differences of different engine technologies and relative payoffs between diesel engines and gasoline engines with technologies. In the cost analysis on page 80, it is unclear how the authors came up with the assumption that the average engine cost difference was $9000. Earlier the report stated that emission control technology on diesels are a major part of the expense. However, very little is mentioned on the cost of the future FC savings technology that would be put on gasoline engines (e.g., package 16 and package 20 technology elements). Is that cost part of the $9000 difference assumption? I guess report #2 specified that cost elements of the different fuel savings technology. This report #3 should refer to this.

- Sections 4.2, 4.3, and 4.4 are all interesting, but somewhat disjointed. For section 4.4, it seems you could apply a driving cycle with a lot of stops and idle to calculate how much you could save with stop/start technology.

de Ojeda

This section focuses on the overall merits of Diesel vs. gasoline fueled engines in the vocational sector. The section, provides a brief and informative description of the Diesel and gasoline presence in the MD market since 1994. Important shifts are highlighted, such as the large price differential between the Diesel and gasoline exhaust after-treatment devices. The cost added of the Diesel option on F-650 is revealing, and is explained with the added aftertreatment devices, fuel injection system and base engine.

Fuel consumption benchmarks are provided for the T270 vehicle for the baseline Diesel engine and a selected technology package for the V6 and V8 gasoline engines. *The report could also make reference to the baseline engine comparison provided in Section 2 for the F-650 (Fig 2.7, page 28).*

The analysis then continues to examine a payback analysis and results are summarized in Table 4.2. Overall the presentation is clear and informative. The analysis makes a powerful case for gasoline, unless the Diesel engine can contain the cost differential.

The discussion on vehicle specifications is limited to a brief discussion on vehicle power demand and a review of the aero, rolling resistance and weight analysis from Section 3. The Charter indicates that a comprehensive "specification sheet" be drawn up. One interpretation is a table with one dimension describing specifications and the other attributes. This work can be of considerable magnitude and may be beyond the scope of the current Report. Nonetheless, the interpretation may be to provide a table as shown below, where for weight the technology specification may be highlighted given the vehicle specification.

Sample of "effect of vehicle specification"

							Vehicle features				Engine features				
Requirements	PWR/TQ	Axle Ratio	Body (Style)	Frame (Weight)	Transmission	Fuel Type	Aero	Crr	Idle Neutral	…	FMEP	Cyl Deactivation	VVA	Downspeed	…
Towing															
Grade															
Distance travel															
Drive Cycle															
Maneuverability															
Visibility															
…															

Lowell

Yes.

Midlam-Moher

Overall this section is not as extensively researched or as comprehensive as the previous section. The discussion is relevant but could be more robust and comprehensive.

Nelson

Section 4 outlines primary characteristics of vocational vehicle operations that may limit the ability to reduce fuel consumption using lower aerodynamic drag or tire rolling resistance, as well as lightweighting to some degree. This does not mean that these technologies should not be pursued; even moderate improvements can deliver consequential fuel savings. Opportunities for vocational vehicle fuel savings for gasoline and diesel versions have most recently been outlined by Lutsey (2015, Table 3). The majority of these technologies have been addressed in the current report, but there may be others that warrant future consideration.

Vehicle sensitivities can be better compared in graphical summaries similar to Figures 3.7 and 3.8 of the T-700 analysis in Report #1. These graphs report percent fuel savings versus progressive improvements in Cd and Crr, and could be developed for vehicle weight reductions. Including several charts of this type in Report #3, also adding T-700 results from the first report, will show differences in vehicle sensitivities more clearly.

A review of T-270 vehicles offered for sale on the website referenced below confirms that a wide range of axle ratios are actively used in the industry. A quick scan showed used vehicles available with axle ratios of 3.9 – 6.17, with 5.29 being the most common. This reinforces the idea of diversity of usages for vehicles in this category, including considerations for vehicle performance needs of grade capability, acceleration, max speed, and startability as well as fuel consumption, as the authors have briefly described.

http://www.truckpaper.com/list/list.aspx?bcatid=27&Manu=KENWORTH&Mdltxt=T270

Nuszkowski

The section on the potential market shift for gasoline versus diesel engines was very interesting and thorough.

4.4-2 Are the assumptions used in the payback discussions appropriate?

Barth

See comment under 4.4-1.

de Ojeda

The assumptions made for the payback analysis are adequate. The assumptions include reasonable ranges for the baseline cost of gasoline fuel and the cost differential between gasoline and Diesel. Though not clearly specified, there is reference to the life of the vehicle which helps frame the payback results (12-15 years).

Lowell

All of the assumptions used in the payback analysis are appropriate except annual miles per truck, which appear to be quite conservative (high). Edition 33 of the Transportation Energy Data Book indicates that in 2012 the average annual miles driven by Class 3 – 8 single unit trucks was 12,816 miles (Table 5.2). It is therefore not clear why the authors chose to use 25,000 miles per year in the payback analysis. The use of a larger assumption for annual miles reduces the payback period for diesel trucks relative to advanced gasoline trucks – as such the author's analysis is quite conservative – for the "average" truck owner the payback periods would in fact be significantly longer than those shown, providing even greater incentive to switch to gasoline medium-duty trucks.

Midlam-Moher

The $9000 assumption for the difference between a diesel and gasoline system needs to be documented. A higher-tech gasoline engine comes with some increase in price (boosting, GDI, etc.) GDI engines may also require particulate matter control in this class of vehicle as well – there is talk of this in the light-duty market based on new regulations.

Need basis for 25,000 miles per year traveled assumption – or make this a parameter that is varied.

The time-value of money is neglected in the payback analysis. Taking this into account is simple and should be included.

Payback periods beyond a certain max vehicle life should be labeled 'Never' in Table 4.2. A 30 year payback period is not really relevant.

Results from Table 4.2 would be easier to view as a figure.

Nelson

The calculations in Section 4.1 of the report cover the range of probable conditions under which a gasoline engine could compete with a diesel version in the T-270. Payback calculations are based on initial purchase price and the fuel consumed, which are the largest vehicle cost items. Other elements that are typically included in payback calculations, described a recent ATRI summary (Torrey and Murray, 2014) are listed below:

- Repair and maintenance;
- Insurance premiums;
- Permits and licenses;
- Tires;
- Tolls;
- Driver wages and benefits.

All costs associated with the items on this list are likely to remain equivalent for both engine fuel types, with a possible exception in the Repair and Maintenance category, which is not accounted for in the Section 4.1 analysis. The ATRI results indicate that across the survey respondents, which include a range of truck classes and is skewed towards long haul, fuel accounted for $0.645/mile of operational cost in 2013, compared to Repair and Maintenance costs of $0.148/mile. An additional factor for payback calculations is residual value, also not considered here. Data reported for the relatively small sample of straight trucks in the ATRI report indicated 32,901 average annual miles per truck, with an average trade cycle of 9 years.

Assuming no differences in maintenance costs, the analysis in Report #3 depends on:

- Difference in vehicle purchase price (V-6 and V-8 both $9000 less expensive than the diesel);
- Differences in fuel consumption between engines;
- Cost of gasoline (taken here as the base);
- Price difference between the cost of gasoline and diesel fuel.

To which we might add,

- Annual mileage;
- Mix and weighting of drive cycle simulations.

Given the variety of applications for this vehicle class, it is difficult to make a case for other than equal weighting of the 6 drive cycles simulated in the study. An increase in assumed annual mileage will make a more favorable case for diesel engines; an annual mileage decrease will favor gasoline engine versions. Including annual mileage as a variable rather than as a constant in the calculations could also be of interest, but it is probably unlikely to significantly change the conclusions of the existing analysis based on 25000 miles annually.

Certainly, the levels and volatility of fuel prices are key to the payback time required to overcome the purchase price differential between gasoline and diesel vehicles. Another version of Figure 4.1 shown in Report #3 comes from the U.S. Department of Energy, Energy Information Administration website (eia.gov), and shows the history of both gasoline and diesel prices in the U.S. (from which Figure 4.1 in Report #3 can be derived). During the period from about 2011 to the end of 2014, volatility of gasoline price has largely driven the differences between the costs of the two fuels, although both fuels experienced significant price drops in the first half of 2015.

Weekly Retail Gasoline and Diesel Prices

Source: U.S. Energy Information Administration

Tax differences between the two fuels cannot account for volatility, however, a certain structural price difference is built into current $/gallon values, as shown in the table below, also taken from the eia.gov website. This impact can change based on public policy regarding fuels, governing authority needs for revenue streams, as well as other factors not strictly market related.

Tax entity	Tax on Gasoline, $/gal	Tax on Diesel, $/gal
Federal	0.18	0.24
State – minimum (Alaska)	0.08	0.08
State – maximum (Pennsylvania)	0.516	0.653
Range per gallon of fuel	0.26 – 0.70	0.32 – 0.90

In the end, the future of fuel pricing is difficult to predict, especially in the current period, but we might say that the most likely scenarios would be in the range of $0-$0.25/gal price penalty for diesel. Payback time is extremely sensitive in this range, as seen in Table 4.2 of the report. Given a 9-year average trade cycle and gasoline prices in the range of $3-$4/gal, there are a number of scenarios for which diesel and gasoline engine solutions could be roughly at parity.

Nuszkowski

Within my area of expertise, which does not include market costs, the discussions are accurate and appropriate.

4.5 Natural Gas Vehicle Cost Survey

4.5-1 Please comment on Section 5. The purpose of the analysis in this section was to describe a survey of current truck market costs for natural gas engines and natural gas fuel storage systems. Are the initial discussions accurate and appropriate?

Barth

- Overall, this is a well written section on the issues of natural gas. The authors hit on all the key topics areas (and the tradeoffs), including engine and vehicle availability, size and weight penalties, engine, fuel, and vehicle prices, fuel availability, and government incentives. It is fairly complete, but it seems that the authors mainly discuss the general disadvantages of natural gas solutions, emphasizing less on the positives (better energy independence, lower GHG, etc.). The transit industry has successful used natural gas in their fleets, overcoming many of the points outlined in this section. I wonder if the authors could discuss a bit more on how it has been successful for transit, but may not be for the vocational trucks.

- Minor: on page 84, the hyphen of "-260 degrees" is on one line and 260 on the next, making it confusing what the temperature is.

- On page 84, the sentence "A slow fill happens at nearly constant temperature, so a loss in energy density does not occur" would be more correct if stated: "A slow fill happens at nearly constant temperature, so a loss in energy capacity does not occur."

- Page 86, the following sentence needs to be fixed: "The CNG system suffers a weight penalty of 2,100 pounds with full tanks, and 2,358 pounds with empty tanks…" I'm not sure where 2358 comes from, and also I think the words empty and full are switched…

de Ojeda

This survey is very informative. The report on natural gas begins with a clear motivation of lower fuel price, lower carbon content leading to lower GHG emissions, and government subsidies. *It may be noted that many municipalities are requiring NG vehicles (in some cases they require from a manufacturer a percent of vehicles to be purchased be NG).*

The report outlines important issues regarding the adoption of natural gas vehicles. *These issues are very important. One personal experience in this area entails following the introduction of natural gas buses in a major municipality in Europe – today operating over 900 natural gas buses in addition to 1200 Diesel buses. The municipality took several years to attain "smooth running". Many of the issues they struggled with are contained in this Section. One issues not mentioned in the report that could be included is safety – in this municipality, the use of natural gas vehicles was restricted to operate above ground. All bus routes that used tunnels were assigned to Diesel buses.*

The report could also include estimates of fill in times. *These may be 25 GGE/hr (with 58 SCFM IR compressor) and up to 50 with accumulator-equipped stations (per experience from 2010-2012 time frame).*

The report has a very good presentation on weight tank. The report shows a natural gas engine and vehicle offerings in Vehicle Classes from 2a through 8. This is accompanied by survey of natural gas vehicle and natural gas storage system prices.

Lowell

The initial discussions about natural gas engines and natural gas storage systems are appropriate and for the most part accurate – see below for areas that require further elaboration.

Midlam-Moher

Yes, this seems to be a solid review of the market with relevant discussions. Note: I do not have deep experience with commercial CNG in the heavy-duty market. Much of this is related to current market trends and offerings.

Nelson

The information presented in Section 5 aligns with other published analysis of the factors and costs associated with the use of natural gas systems in commercial vehicles. Listings of engine offerings in Report #3 are consistent with earlier summaries presented in Table 7.1 of an ACT whitepaper (ACT, 2012), and cover updates in product offerings since that time. The most commonly mentioned considerations related to the adoption of natural gas vehicles are covered in Section 5.0:

- Vehicle acquisition costs – driven by both engine and on-board fuel storage differences;
- Natural gas versus diesel fuel price differentials;
- Fueling station availability and infrastructure;
- Government incentives;
- Downtime concerns due to natural gas re-fueling times;
- General discussion of maintenance;
- Efficiency differences between diesel and natural gas solutions, including engine efficiencies, weight and aerodynamic effects;
- Impact of wheelbase is a consideration discussed briefly in Section 5.0 that is not often covered elsewhere.

An overview of payback and operational considerations for natural gas vehicles from a fleet perspective is reported by J.B. Hunt (Mounce, 2014). This whitepaper covers purchase price upcharge for natural gas options, observed differences in fuel consumption, vehicle weight comparisons, fuel cost comparisons, as well as presenting two hypothetical scenarios for return on investment calculations, looking at natural gas versus diesel over a 5-year analysis period. Additional maintenance costs were estimated at $0.02-$0.04 per mile for spark-ignited NG engines. Questions of resale, or residual values, of natural gas vehicles are at present unknown. It should be noted that this fleet continues to study the performance and opportunities of natural gas options.

Several elements that can support future ROI analysis, but which are not included in Report #3, are listed below:

- Costs to upgrade existing maintenance facilities plus routine operational maintenance costs for natural gas applications;
- DEF costs for diesel, estimated at around 2-2.5% of fuel costs;
- Comparison of natural gas versus diesel options in terms of risks and potential to meet emissions requirements across the range of GHG and criteria pollutants. A recent article discusses latest estimates of potential methane emissions associated with fleet conversion from diesel to natural gas fuels (Camuzeaux et al., 2015).

Nuszkowski

Within my area of expertise, which does not include market costs, the discussions are accurate and appropriate.

4.5-2 Are the natural gas vehicle survey details correct, comprehensive, and sufficiently explained?

Barth

See comment under 4.5-1.

de Ojeda

Yes, the survey appears accurate. It is comprehensive and well explained.

The sensitivity of pump prices to raw fuel prices from Table 5.7 seemed surprising, specifically the higher % increases for gasoline and Diesel vs. natural gas, but the numbers check. It highlights the impact of a low base cost for the natural gas fuel.

The reporting fuel efficiency by Paper Transport and Kroger are important “real-life” reference data. *It may be worth inserting these vehicle configurations on the SWRI model tool to study the breakdown of the losses. The natural gas vehicles are reported as having less aerodynamic profiles, weight increase and worse than Diesel efficiency. This could be a good “case study” to be included in the report.*

Lowell

- In section 5.1, page 84 it is noted that “if a CNG tank is filled rapidly, usable capacity is reduced by about 20%. Only a slow (typically overnight) fill will get the tank to full capacity”. I do not believe that this is an accurate statement. It is typical and acceptable for fast-fill CNG stations to use a temperature compensated fill algorithm to allow up to 4,500 psi in the cylinder at the end of fueling, as long as the “settled pressure” once the gas and cylinder has cooled to 70 degrees F would be no more than 3,600 psi (see, for example http://www.afdc.energy.gov/bulletins/ 2014_09_18_CNG_Temp.html). With proper temperature compensation even fast-fill stations should be able to fill a tank to greater than 80% rated capacity.

- I believe that section 5.4 (natural gas prices) would benefit from a longer-term historical comparison of natural gas versus diesel price trends. US DOE Clean Cities has been issuing quarterly reports on natural gas and diesel fuel prices at public fuel stations since May 2000 (http://www.afdc.energy.gov/publications/search/keyword/?q=alternative%20fuel%20price%20report) and this data could be used to provide this historical perspective. The salient point that would be gained from this comparison is that prior to 2008 natural gas was generally more expensive than diesel fuel most of the time, but nonetheless prices for both fuels tended to go up and down together. Starting in 2008 natural gas and diesel fuel prices were uncoupled. Since 2008 natural gas has generally been less expensive than diesel fuel, but more importantly diesel prices have been more volatile and natural gas prices have not responded to the same price pressures as diesel. Diesel fuel prices have and continue to respond to global macro-economic and political forces that affect global supply and demand for crude oil, while natural gas prices have and continue to respond to local supply and demand, driven by the continuing glut of U.S. natural gas production from the shale gas revolution in the US. This means that there is much greater uncertainty as to the future relationship between natural gas and diesel prices than there has been in the past, which significantly increases the risk of a decision by a vehicle owner to invest in the purchase of a natural gas vehicle.

- In Sec 5.7.1 the authors note that current natural gas engines have significantly lower thermal efficiency than current diesel engines, which is certainly true. However, in Section 4.1 of the report the authors make the case that the future engine changes modeled for this project could significantly narrow the current gap between diesel and gasoline engines in terms of net efficiency, making gasoline engines more cost-effective than diesel engines, especially for medium-duty vocational trucks. The authors should specifically comment and discuss whether the specific engine technologies modeled here for gasoline engines would also be applicable to future natural gas engines (why or why not) and therefore whether the current thermal efficiency gap between diesel and natural gas engines could be similarly narrowed.

- In section 5.7.2 the report says that "Both fast-fill CNG and LNG vehicles take longer to fill than conventional diesel or gasoline vehicles". Some transit bus fleets (for example MTA New York City Transit) have been able to achieve comparable fill times for diesel and CNG buses using very large fast-fill CNG fuel stations. For a 40-gallon fill (typical of NYC buses) the fill time for diesel and CNG buses varies by less than a minute. To achieve this level of performance a very large and costly fuel station is required, but it is possible.

- In section 5.7.3 when discussing the weight penalty associated with natural gas vehicles the authors state "This weight penalty for natural gas vehicles has a modest negative effect on fuel consumption. Based on the results of the modeling conducted here (weight sweeps) the authors should be able to quantify the range of this fuel economy penalty for different types of natural gas trucks.

- The natural gas vehicle survey does not include any discussion of greenhouse gas (GHG) emissions benefits or dis-benefits of natural gas trucks relative to diesel and gasoline trucks. Given that this report is in support of joint NHTSA/EPA rules to implement combined fuel economy and GHG regulations I believe that the report should include such a discussion. The discussion/analysis should account for net GHG benefits/dis-benefits based on both fuel carbon content and real-world differences in net thermal efficiency for natural gas versus diesel and gasoline trucks. The analysis/discussion should also include upstream emissions of CO2, CH4, and N2O from fuel production and transport, to provide a full wells-to-wheels comparison of natural gas trucks relative to diesel and gasoline trucks.

Midlam-Moher

I did not find any errors or omissions and felt explanations were good. See note above in 5-1.

Nelson

Explanations of the current state of natural gas options and considerations are suitable and properly described. Other details are discussed in the response to Question 5-1.

Nuszkowski

Within my area of expertise, which does not include market costs, the details are accurate and comprehensive, and sufficiently explained.

4.6 Project Conclusions

4.6-1 Please comment on Section 6. The purpose of this section was to present project conclusions. Did this section effectively summarize the conclusions of each section of the report?

Barth

- Overall, the conclusions section is good. Just a few minor comments:
- On page 98, one conclusion is "Achieving this level of benefit requires the use of complex and expensive technologies that are not yet fully developed, such as a waste heat recovery system." In this report, nothing was mentioned about the cost of the technology, I assume that information is in report #2.
- The conclusions seem to only cover Sections 2 and 3; sections 4 and 5 are not really mentioned at all in the conclusions section. It would be good to at least have a few key conclusions about the natural gas vehicles.

de Ojeda

Conclusions should identify technology segments for regulators, OEMs, Tier I suppliers, and in general consumers that will positively impact fuel savings while meeting current or future emissions standards. The conclusions, at least should point to specific technologies that merit further investigation. The report does this.

Conclusions appear they could be more focused. The authors may want to see if they can be made more specific, possibly more systematic, breaking them down by category, and including some evaluation regarding the complexity or risk (such as indicated earlier in Section 2).

Lowell

Yes, this section did effectively summarize the conclusions of the report with respect to long haul trucks.

Midlam-Moher

The summary does a good job at highlighting Section 2 but does not highlight results from Sections 3, 4, and 5.

Nelson

Section 6 is well written, concise, and clear. Descriptions of potential fuel savings, function and impacts of key technologies and packages, and relevant drive-cycle results are comprehensive without getting lost in details. These are by far the most important conclusions of the study project.

That being said, conclusions from the sections on hybrid solutions, payback calculations for gasoline versus diesel engines in vocational vehicles, and the analysis of natural gas fuel solutions are missing. It is not evident where these items could be inserted into Section 6 without diminishing the impact of the findings contained in this chapter in its current form.

Nuszkowski

The natural gas and hybrid technology results are not discussed in the conclusions.

4.6-2 Did this section effectively present overall conclusions?

Barth

See comment under 4.6-1.

de Ojeda

Tables 6.1 and 6.2 are rather difficult to follow.

- Section 2 focuses on % savings with respect to each engine baseline.
- Here we have a comparison of the gasoline engines with respect to the Diesel. The numbers should readily come out from the previous tabulated results but they don't. I would strongly suggest that this be done: reference what tables in Section 2 are used to obtained the numbers shown.

Lowell

- The discussion of gasoline versus diesel engine results in sections 6.2 should include a direct discussion of the difference between the modeled gasoline and diesel engines on an energy equivalent basis. Perhaps the easiest way to do this would be to include another table, in addition to tables 6.1, which shows "CO_2 Emissions Penalty on Drive Cycle at 50% Payload", in addition to the existing data on "Fuel Consumption (gallons) Penalty on Drive Cycles at 50% Payload"

Midlam-Moher

Yes – with the caveat from 6-1.

Nelson

Table 6.3 presents the key conclusions in a compact format. However, the approach used to derive the fuel savings percentages in Table 6.3 from the results tables in Section 2 should be explained.

While not at the same level of importance as the results of Table 6.3, conclusions on additive versus non-additive technologies, enabling technologies, and opposing technologies should be addressed if possible.

Nuszkowski

This section presented the overall conclusions.

4.6-3 Are any important conclusions missing or inadequately explained?

Barth

See comment under 4.6-1.

de Ojeda

The Conclusion Section lacks a description of synergies among technologies. Conclusions could include what technologies work well with one another, and which do not. This was emphasized in the Charter and would be important to include.

The report establishes other fuel savings opportunities that were not able to be included in Report 3, such as reduced cooling fan power demand and improved efficiency of engine driven accessories such as hydraulic systems. It is good that this be pointed out and hopefully can be taken up in the future in a similar study.

Fuel savings are highly dependent on duty cycles. The report makes a strong case that vehicle and engines need to be well matched given the application. As in the case of the pick-up market, the installation of the 385 HP and 850 lb-ft Diesel engine is not needed unless trucks operate near GCW – whence it is important. The use of the downsized V6 provides significant fuel savings.

Lowell

- The discussion of gasoline versus diesel engine results in sections 6.3 should include a direct discussion of the difference between the modeled gasoline and diesel engines on an energy equivalent basis. Perhaps the easiest way to do this would be to include another table, in addition to table 6.2, which shows for "CO_2 Emissions Penalty on Drive Cycle at 50% Payload", in addition to the existing data on "Fuel Consumption (gallons) Penalty on Drive Cycles at 50% Payload"

- In section 6.4, table 6.3 it is not completely clear whether the stated reductions from "engine" and "vehicle" are additive or not. To make this clear the table should include, for each vehicle type, a Total line identifying the range of total fuel reductions possible from both engine and vehicle technologies together. If, for any of the vehicles, the engine and vehicle reductions are not fully additive this should be briefly noted – particularly since one of the purposes of this project was to explore the "additive nature and synergistic relationships between different options for fuel economy improvement".

  It would also be helpful if this table included the range of percentage reduction in CO_2 emissions available from improved engines for each vehicle type, particularly for those vehicles for which both gasoline and diesel engines were modeled.

Midlam-Moher

No – with the caveat from 6-1.

Nelson

Interpretation of Tables 6.1 and 6.2 can be confusing. A positive percentage means greater fuel consumption (accounting for differences in energy content between the fuel types and the thermal efficiency of the respective engines) of the V-6 or V-8 gasoline engines compared to a projected 2019 diesel baseline. A negative percentage means the gasoline engine consumes less fuel than the diesel, again considering both fuel energy content and engine thermal efficiency. One way to clarify the reading of the tables is to provide a short explanation that walks through one column in each table.

Nuszkowski

The executive summary and the conclusions section did not reemphasize the limitations and/or accuracy of the model and the reported percent fuel reductions.

4.7 Appendices

4.7-1 Please comment on the four report appendices. Do they provide sufficient technical detail in support of the report sections?

Barth

- Overall, the appendices cover a lot of details in terms of the vehicle technology combinations and their results. There is sufficient technical detail in these sections.
- It is clear that the appendix on the hybrid systems was written by different authors, the flow of that section is different, but adequate.
- Some of the tables and figures in the appendix are inconsistent in style and formatting, but the information content is adequate.

de Ojeda

Yes. They provide very good technical background to the sections of the report both for engine and vehicle (which includes a strong section on axle, governor speed and engine alternatives), and hybrid technologies.

Lowell

Yes, the appendixes provide sufficient technical detail.

Midlam-Moher

As described previously, the Appendices provide information on the inputs to the modeling approach – but not much detail on how the technology maps were derived. I think this is OK as that is described in detail in Report #1 which was peer reviewed as well.

Nelson

Vehicles and vehicle technology input data are properly and adequately described in Appendix C for the purposes of the simulations. For clarity concerning the rolling resistance coefficients, it is recommended that the updated discussion of the derivation of Crr values leading up to Table C.9 of Appendix C in Report #1 also be included in Appendix C of Report #3, just before Table C.18.

Some additional clarifications for the Appendices are listed below:

- In Appendix B, Section 1.1 of Report #3, does “original” baseline refer to the 2011 production DD15 for which a test cell dataset was available, or does the term refer to the simulation result of “Technology #7 – Asymmetric Turbo” from Report #1, which was the exercise to model a 2013 DD15? This point should be clarified for both the text and figure titles in this section.
- To reinforce the current study a stand-alone report, it may be beneficial to include the graphs of the drive cycles again in Report #3.

- Aerodynamic drag coefficients Cd w/Trailer of the Dodge Ram and baseline and reduced CdA of the T-700 do not match in comparing Table C.17 of Report #3 with Table C.8 of Report #1.
- Baseline tire rolling resistance coefficient given in Table C.18 of Report #3 for the Dodge Ram does not match the value shown in Table C.9 of Report #1 (as a side note, the Reduced value of Crr reported for the Dodge Ram in Table C.9 of Report #1 should have been 0.005460, and not 0.05460, given the baseline Crr listed in that table).
- Report #3 Sections 2.3.2.4, 2.3.2.5, 2.3.2.6, 2.3.2.7 and 2.3.2.9 refer to Appendix D for discussion of waste heat recovery systems. Section 5.3 also makes reference to Appendix D for information on natural gas vehicle prices. However, Appendix D in the draft of Report #3 is devoted to hybrid systems only.

Nuszkowski

The appendices show sufficient technical details. Enough details are shown that similar fuel consumptions results could be reproduced.

4.8 General Comments

4.8-1 Describe your overall assessment of the organization, readability, and clarity of this report, including any specific recommendations for improvement or changes needed.

Barth

- Overall, the report is well organized and pretty clear. Just a few comments:
- As mentioned earlier, the executive summary makes a lot of assumptions in terms of what is already known, therefore it may have limited use as a stand-alone document.
- Some of the different sections in the report end abruptly, without any concluding sentences which sometimes leaves the reader hanging.
- In the discussions about all of the different technology combinations it gets confusing in terms of what the baselines are. All the information is there, however it is necessary to read some sections a few times before it sinks in.

de Ojeda

The report is very well organized, it reads well and is clear.

- The simulation of combined technologies is very complete. The report relies on a strong and systematic modeling approach,
- The cycles, vehicle, and engines chosen are very representative and adequate to fulfill the task.

Lowell

- In general this report is well organized, readable, and clear. However the reader's ability to interpret the results and their implications would be enhanced by the following changes:
    - Reorder the data in all tables and figures in Section 2, so the results are consistently shown with the different drive cycles in order of low to high engine load from left to right

- For all tables and figures in Section 2 add one more column which includes results for a weighted average of the CARB, 55 MPH, and 65 MPH cycles, as currently used in GEM for certification under NHTSA/EPA Phase 1.

- In sections 2.3.5.16, 2.3.7.1, and 2.3.9.17 add tables, and explanatory text, which directly compare the modeled gasoline and diesel engine options on an energy-equivalent basis (i.e. % reduction in btu/mi or in btu/cycle; or % reduction in gasoline-gallon equivalents (GGE) per mile or GGE/cycle; or % reduction in carbon dioxide (CO2) emissions per mile or per cycle.)

- Provide examples of the types of changes that would be required to existing truck models to achieve the different levels of C_d and C_r reduction included in the parameter sweeps.

Midlam-Moher

Section 2 is very, very figure/table dense. To the point that it is very difficult to make high-level conclusions. As stated previously, providing some summary plots of the data that consolidate results into a single figure would be helpful.

Nelson

The report is extremely detailed in the descriptions of selected vehicles and their characteristics, the fuel savings technologies, engine technologies in particular, as well as the simulation models used and engine simulation outputs. As in the first report, this can make for some difficult reading. However, since it is infrequent that a study of vehicles, engines, and technologies of this breadth is undertaken, it is felt that the level of detail will in fact be helpful over time, to document as thoroughly as possible the way each technology is understood to work, the assumptions and approximations made in simulations, and how results were interpreted.

The ordering of the main report sections is logical. It is clear how the information in one section is supported by the analysis of the preceding section.

Some comprehension difficulties may arise due to the changing order in which vehicles and engine technologies are presented from section to section. For example, in the Executive Summary a discussion of the DD15 engine and T-700 truck is followed by the discussion of medium-duty and pickup truck gasoline engines, whereas in Section 2 the medium-duty diesel engine discussion comes first. Vehicle technology packages are first described for the F-650 in Section 2, but the first parameter sweeps are presented for the Ram pickup in Section 3. A consistent sequencing of vehicles and engines throughout the report would be very helpful for the reader in keeping the progression of technology packages clear.

As mentioned in the response to Question 2-1, the path taken from the initial 2011 baseline DD15 engine through the sequence of interim model upgrades leading up to the 2019 DD15 baseline should be summarized in one paragraph. Then consistent terminology should be used to refer to the specific baselines throughout the rest of the report.

The process of engine model development is given in Section 2.2, but it is difficult to get a sense of what information is used for model building and calibration, and what is used for model validation. Even though the reader is referred to Appendix A for details, a summary statement describing which charts are used for quality checks during the modeling process reinforces confidence in the approach.

Other recommendations that could aid the reader's comprehension could include (some items mentioned earlier in this review):

- List each DD15 and T-700 technology package in separate paragraphs in the Executive Summary.
- A table of study vehicles, engines, and drives cycles included in the Introduction, as mentioned in the response to Question 1-1.
- Move Section 2.3.9.17, referring to the F-650, to its proper location in the report, or update the section title. (This section currently sits in the middle of the Ram engine discussions.)
- Bring T-700 sweeps results for Cd, Crr, and weight into Report #3, and present the sweeps results for all vehicles in the same format as shown in Figures 3.7 and 3.8 of Report #1.

Nuszkowski

Overall, the report was organized, readable, and clear with only minor corrections needed. See other sections for the changes needed.

4.8-2 Is the information provided in the report and appendices sufficiently detailed to thoroughly document all essential elements of the study? If not, what additional information is needed?

Barth

- There is sufficient detail in the report, both in the main body and in the appendices. But sometimes you need to track multiple things between sections (and tables) of the report, and the appendices to fully understand the details. This is mainly due to the complexity of the analysis.
- As mentioned previously, it is not clear to the reader how the different combinations of technologies were chosen, it seems somewhat ad-hoc in some cases. The reader is left wondering if other technologies could also be woven in, such as different types of hybridization.

de Ojeda

Yes, the report is technically very detailed and is accompanied by informative Appendices.

The addition of the following items may strengthen the report:

- Incorporate a summary of GHG Emission and Fuel Efficiency standards,
- Fuel saving estimates complemented with a cost-risk “complexity index”,
- The Conclusion Section should detailed the sources for the results shown on Tables 6.1 and 6.2.

Lowell

Yes, information provided in the report and appendices is sufficiently detailed to thoroughly document all essential elements of the study.

Midlam-Moher

Yes. See earlier comments.

Nelson

The updated discussion of the derivation of Crr values leading up to Table C.9 of Appendix C in Report #1 should be repeated in Appendix C of Report #3, just before Table C.18.

Nuszkowski

The hybrid technology section needs a more complete and thorough discussion.

4.8-3 What are the strongest and weakest parts of this report? How can the weakest parts of the report can be strengthened?

Barth

The strongest part of the report was section 2, in terms of the analysis and comparison of the different technology combinations. Sections 4 and 5 were both written very well and covered the key areas of costs and tradeoffs. The weakest part of the report probably was the executive summary which probably doesn't do too well as a stand-alone document, it is really just a summary that you can understand once you have read the entire report.

de Ojeda

The simulation, technology-packages description and discussions are very strong.

- The cycles selected highlight how different engine and vehicle technology combinations perform across a range of applications. Results illustrate how some technologies are sensitive to payload in a given drive cycle,
- The report clearly indicates and justifies the assumptions used,
- The findings are well aligned to the simulations,
- The payback study is very informative and the analysis makes a powerful case for gasoline, unless the Diesel engine can contain the cost differential.

The reporting of fuel savings is mainly done with respect to each engine baseline. This is reasonable given the unique characteristics of each platform. Nevertheless it would seem necessary to compare each engine platform in the case of the MD and Pickup sector.

Lowell

- The strongest part of the report is Section 2.
- The weakest part of the report is the Executive Summary - it is too long and complicated. I believe that the report would benefit from a shorter and simpler Executive Summary, more along the lines of the discussion is Section 6, to include: 1) a short back ground on the goals and methodology of the study, 2) a simplified discussion of the types of engine and technology packages simulated (without the very detailed description of each individual engine and technology package), and 3) a high level discussion of the over-all conclusions of the study (without a detailed description of modeling results for each engine and technology package).

Midlam-Moher

The weakest part is Section 4 and Section 3. Section 4 is a simple analysis (which is OK) but assumptions are not well documented and it is not a very complete analysis (see comments.) Section 3 could also use additional explanation regarding some of the curves (see comments.)

Nelson

The most impactful parts of the report document the combined engine-vehicle technology package simulation results.

While not particularly weak, the sweeps section of the report could be strengthened by including the standard equations for the components of road load – aerodynamic drag, tire rolling resistance, and vehicle inertial effects due to accelerations (excluding grade for the moment) – then charting the proportion of power demand due to each road load component during the execution of a particular drive cycle. These proportions are frequently referred to in the explanations of the various vehicle sensitivities. The exercise could be accomplished for selected cycles for any vehicle, and would help illustrate the changing proportions of engine power required to overcome each component as the cycle proceeds.

Nuszkowski

The wide breadth of combined vehicle and engine technologies analyzed on many different drive cycles was the strongest part of the report.

The weakest part of the report was technologies that were not synergistic or not additive were not discussed. In addition, the hybrid technology section was weak. The discussion was incomplete and did not flow with the rest of the report.

4.8-4 Please provide any other comments you may have on this report.

Barth

Overall the information provided in the report is sufficiently detailed; various comments on specifics have been provided above.

- As mentioned as part of the evaluations of Report #1, one key thing that would be helpful in the introduction is some better scoping sentences. Fuel economy is affected by a number of different things, generally categorized into four areas: 1) vehicle technology effects; 2) vehicle fuel effects; 3) driver behavior effects; and 4) roadway infrastructure effects. Obviously this report deals with the area of 1), i.e., what kind of on-board vehicle technology exists that can improve fuel economy. Even though it is out of the scope of the report, different fuels and fuel additives have an effect on fuel economy, there is significant research and products in this area. Regarding 3), there is now technology that affects how a driver operates the vehicle. Example of this technology include eco-driving aids and real-time navigational aids showing roadway status (e.g., upcoming grade, traffic, etc.). In a sense, this driver feedback technology changes the “driving cycle” that is applied to the vehicle in a typical testing environment. When employed, this eco-driving feedback technology allows for different levels of fuel economy savings, see DOE vehicle technology program references (e.g., see http://energy.gov/sites/prod/files/2014/07/f17/vss087_verma_2014_o.pdf and http://energy.gov/sites/prod/files/2014/12/f19/2014_amr.pdf). Again, this should at least be mentioned maybe in the introduction. Regarding 4), there are roadway infrastructure and traffic operation techniques that can also affect vehicle fuel economy. These include things like traffic signal synchronization, variable speed limit techniques on freeways, adaptive ramp metering, etc. Although this is not vehicle technology per se, this roadway technology can improve overall traffic fuel economy. Again, this is outside the scope of this report, but perhaps it should still be mentioned in the introduction.

de Ojeda

The discussion on vehicle specifications (Section 4) is limited. The charter indicates the need of a comprehensive “specification sheet” be examined for the MD sector. It may be worth attempting to sketch this, possibly along the lines of the table shown in the commentary of Section 4 above.

Lowell

None.

Midlam-Moher

No additional comments.

Nelson

The focus of this report is fuel consumption. But as multiple technologies are combined there are greater opportunities for one technology to impinge on non-fuel related performances of another. In the case of tires, the primary functions are to: 1) support the weight of the vehicle and payload; 2) transfer forces between the vehicle and road surface for steering and vehicle control, acceleration, and braking; and 3) isolate payload and vehicle occupants from driving surface roughness or irregularities (Lindenmuth, 2005). Ancillary performances include tread wear life, tire rolling resistance, and durability, the latter being of particular significance for heavy duty truck tires in order to support retreading. Fuel savings systems that may combine to increase mechanical or thermal stresses on tires, or any other vehicle component for that matter, will require careful integration to ensure that the final vehicle solutions continue to deliver the expected suite of performances at the component level.

Nuszkowski

Some minor comments and corrections:

Throughout the document:

- Replace the term “RPM” with “engine speed”
- Combine one sentence paragraphs with other paragraphs
- Replace “&” with “and”
- Change “max” to “maximum” and ‘min” to “minimum”
- Replace just “speed” with the more specific “vehicle speed”
- Figure title spacing is inconsistent.

In the executive summary:

Please clean up the short paragraphs and lists without bullet points.

“1% combustion efficiency improvement” should be “1% thermal efficiency improvement.”

Introduction:

Page 7. Table 2.8 and 2.9 references to “P2” and “P3” was this supposed to be “P12” and “P13”? Please check all the package references.

Page 9, first paragraph “pluses” should be “pulses”

Section 2:

In the tables of engine technology combinations, the term “1% efficiency improvement” is misleading. Please change to “1% thermal efficiency” improvement.

Page 28. F-650 is mentioned as having “vehicle packages 2 through 5.” From Table 2.8, the F-650 does not have vehicle packages in this number range.

Page 29. Table 2.14 also shows these incorrect package references.

Page 33. “sees a 3% to 4% with the automatic” should be “sees a 3% to 4% benefit with the automatic”.

Page 44. Table 2.20 has two “2019 ISB” rows.

Page 46. The last paragraph should not be centered.

Page 48. Section 2.3.9.10 has a reference to “Package 1” which is incorrect.

Page 51. “Ram vehicle packages 2 through 5.” The Ram does not have vehicle packages in the range of 2 through 5.

Page 55. Figure title at the top of the page.

Section 4:

Define “VMT” in the abbreviations section.

Appendices:

Page 122. Inconsistent spacing.

Page 144. Make a complete paragraph for the figure lists.

4.9 Overall Recommendation

4.9-1 Based upon your review, indicate whether you find the report: (1) acceptable as is, (2) acceptable with minor revisions, (3) acceptable with major revisions, or (4) not acceptable. Please justify your recommendation. If you find the report acceptable with minor or major revisions, be sure to describe the revisions needed.

Barth

Based on my review, the report and appendices are acceptable with minor revisions. There are a variety of comments and suggestions made in the above text that the authors could address.

de Ojeda

I find the report acceptable with minor revisions.

The report presents an excellent simulation study throughout a very comprehensive list of combinations for engine and vehicle technologies. It is very informative.

Minor revision requested are:

1. Correct typos as indicated in this charter revision (see earlier sections)
2. Update Conclusions to specify more systematically a breakdown of fuel savings per category, including evaluation regarding the complexity or risk.
3. Clarify how the entries on Table 6.1 and 6.2 were calculated. Given that the comparison approach differs from the earlier section, please show how they are estimated based on the results from Section 2.

Lowell

This report is acceptable with minor revisions. The required revisions are noted above, in particular: 1) re-order data in tables and charts to show drive cycles from low to high engine load from left to right, 2) compare gasoline and diesel engine options directly on an energy-equivalent and/or GHG basis in addition to comparing them on a volumetric fuel basis, 3) use consistent numbering in the description of the engine and vehicle technology packages in tables 2.2, 2.3, 2.4, and 2.5, and 3) shorten and simplify the Executive Summary. These required minor revisions are necessary to enhance the ability of readers to understand the interconnections and implications of the study results.

Midlam-Moher

Acceptable with minor revisions.

The revisions requested would be to better document the assumptions used which are described above. The majority of my comments on this work are in regards to clarity rather than criticism of the technical side of the work.

Nelson

I would recommend the report be published with (a) minor revisions to improve readability and for minor corrections, specifically addressing clarification of the DD15 baselines, the bullet points outlined in the response to Question 8-1, and the updates to the appendices described in the responses to Questions 7-1 and 8-2.

The technology reports within the scope of this project provide thorough, comprehensive analysis of the opportunities for fuel savings in the commercial truck sector, and should serve as valuable references for both rulemaking and for future research.

Nuszkowski

Acceptable with minor revisions. Please see other sections for my revisions.

4.10 Additional Comments Provided

Nelson

References:

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23. Rotz, D. and Ziegler, M., "Super Truck Program: Vehicle Project Review, Recovery Act – Class 8 Truck Freight Efficiency Improvement Program", June 19, 2014, Vehicle Technologies Office Annual Merit review and Peer Evaluation Meeting, http://energy.gov/sites/prod/files/2014/07/f17/arravt080_vss_rotz_2014_o.pdf.
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APPENDIX A

REVIEWER CURRICULUM VITAE

MATTHEW J. BARTH
Jacques and Eugene Yeager Families Endowed Chair; Professor of Electrical Engineering
Director, Center for Environmental Research and Technology
College of Engineering, University of California, Riverside, CA 92521
Tel: (951) 781-5782 Fax: (951) 781-5790 E-mail: barth@ee.ucr.edu

Education

1990 - 1991	Post-Doctoral Research Scholar, Systems Engineering; Osaka University, Japan
1986 - 1990	Ph.D. (1990), Electrical and Computer Engineering; University of California, Santa Barbara
1986 - 1987	Visiting Research Scholar, Information Engineering; University of Tokyo, Japan
1985 - 1986	M.S. (1986), Electrical and Computer Engineering; University of California, Santa Barbara
1980 - 1984	B.S. (1984), Electrical Engineering / Computer Science; University of Colorado, Boulder
1982 - 1983	Study Abroad Student, Electrical Engineering; University of Stuttgart, West Germany

Employment

1992 - present ***University of California-Riverside:***

Electrical Engineering: Professor 2003-present; Associate Professor 1998-2003; Adjunct Assistant Professor 1992-1998. Part of Intelligent Systems Group. Cooperative faculty appointments: Mechanical Engineering, Chemical/Environmental Engineering.

UCR Center for Environmental Research and Technology (CE-CERT): Director 2007-present; Interim Director 2004-2007; Associate Director 1998-2003; Research Faculty 1992-1998. Research focus: intelligent transportation systems for the environment, transportation/emissions simulation modeling, sustainable energy systems, electric-drive vehicles, intelligent sensing/control.

1990 - 1991 ***Department of Systems Engineering, Faculty of Engineering Science, Osaka University, Japan***: Visiting Research Postdoctoral Fellow. Investigated transportation technology, mobile agent navigation, computer vision, and control.

1985 - 1990 ***Center for Robotic Systems in Microelectronics, University of California, Santa Barbara***: Graduate Research Assistant. Member of the robot perception group. Emphasis on attentive vision techniques, multi-level feedback sensory/control mechanisms, machine color vision, and embedded systems.

1985 - 1986 ***General Research Corporation, Santa Barbara, California***: Member of the Technical Staff, Advanced Technology Division. Developed data acquisition systems and electronics associated with electro-optical electromagnetic photonic field sensors.

1979 - 1984 ***Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder***: Command controller of university research satellite, data logging and formatting.

Research Interests

Transportation/emissions modeling, intelligent transportation systems, vehicle activity analysis, sustainable energy systems, electric vehicle technology, intelligent sensing /control, multi-agent systems.

Professional Service

Memberships:

- Institute of Electrical and Electronic Engineering (IEEE): Member-1990, Senior Member-2000, Fellow-2014, Intelligent Transportation System Society, Vehicular Technology Society
- Institute of Electrical and Electronic Engineering (IEEE): Intelligent Transportation System Society President 2014-2015; President Elect 2013; Vice President-Conferences 2011-2012;
- Transportation Research Board: Member, Transportation and Air Quality Committee; Intelligent Transportation Systems Committee, New Transportation Technology Committee
- U.S. EPA Mobile Sources Technical Review Subcommittee: Co-Chair, Modeling Workgroup
- ITS America: Sustainable Transportation Committee
- Southern California Association of Governments: Committee Member, University Advisory Group

Awards and Honors

- Yeager Families Endowed Chair in Engineering at UC Riverside, 2007 – present
- IEEE Fellow, for pioneering research in Intelligent Transportation Systems, 2014
- City of Riverside, Smart Riverside Innovation Honoree, 2013
- Federal Highway Administration Connected Vehicle Technology Challenge Award, 2011.
- Innovative Transportation Systems Clean Air Award, Air Quality Management District (with Honda), 2010
- Member of the Governor's Expert Review Panel on Transportation Research and Technology, 2008
- Transportation Research Board Pyke Johnson Award , 2006
- Invited Speaker, National Academy of Engineering's 2006 Annual Symposium on Frontiers of Engineering
- Discover Magazine Awards for Technological Innovation, National Finalist 2001
- Tau Beta Pi: Outstanding Teaching Assistant in Electrical and Computer Engineering, 1988
- NASA: Public Service Group Achievement Award for the control and operations of university satellite, 1984

SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

Dissemination of Research

- Journal Papers: 66; Refereed Conference Papers: 190; Books and Book Chapters: 11; Technical Reports: 141
- U.S. Patents: 8; International Patents: 6
- Presentations, Invited Talks, Keynote Speech (2010-2013): 44

Advising & Mentoring

- Postdoctoral Scholars Directly Supervised: 8
- Graduate Students graduated as Major Advisor: 8 Ph.D. (7 in progress), 22 M.S. (2 in progress).
- Undergraduate Student Researchers Directly Advised: 38

Recent Research Grants

- Total Number of New Grants as Principal Investigator (2010 - 2013): 18 for $6.1M
- Additional Number of Grants as Co-Investigator (2010 - 2013): 4 for $1.2M

William de Ojeda, PhD, PE

EDUCATION

Illinois Institute of Technology	Ph.D. Mechanical and Aerospace Engineering, '96
University of Virginia	M.Sc. Mechanical and Aerospace Engineering, '92
The Cooper Union	B.S. Mechanical Engineering, '90 Awarded **Stefano Excellence Award** for Capstone Design

INDUSTRIAL EXPERIENCE

WM International Engineering, Darien — 2014

Director of Engineering

Responsible for development of fuel injection and charge air systems for advanced Diesel, Gasoline, Natural Gas, Dual Fuel and alternative fuel Powertrains. Work includes design, prototyping, controls and benchmarking.

Navistar, Lisle — 1997-2014

Technical lead on the SCR engine deployment (2013-14)

Lead system integration and execution of air and fuel strategies and OBDII features on new HD product.

Manager, Advanced Combustion and Controls (2005-2012)

Principal Investigator on **DOE Supertruck** program (2010-2012)

Responsible for integration of new technologies onto engine and vehicle platform including Variable Valve Actuation, new High-Pressure Common Rail, Turbo-compounding and Organic Rankine Cycle, base engine improvements, aftertreatment systems such as DPF, SCR and LNT Supervised staff across multi-disciplinary specialties, multiple engine dynamometer cells, and subcontractors including ANL, Federal Mogul, and BOSCH. Program sponsored by DOE grant **DE-EE0003303** High Efficiency Engine and Vehicles.

Principal Investigator on **Low Temp Comb Demonstrator** (2005-2010)

Directed redesign of 6.4L engine to meet 2010 emissions based on low temperature combustion. Scope and major milestones of program included design of injectors, combustion chamber, turbocharger and EGR system, and a new electro-hydraulic variable valve actuation system. Developed prototype ECU to run all engine functions including combustion feedback. Reposabilities included the assembly of a team of engineers in the areas of controls, fuel injection, CAD, combustion, and elecro-hydraulics. Supervised subcontractors including LLNL, UC Berkeley, Borg Warner, Siemens, and Ricardo. Program sponsored by DOE grant **DE-FC26-05NT42413** High Engine Efficiency and Clean Combustion Program.

Sr. Product Engineer, Advanced Technologies (2001-2005)

Responsible for dSPACE/Matlab Simulink software and integration into the early Siemen's EDU prototypes. Models focused in air-fuel management strategies on 2007MY V8 engine product and the transition to MAF and TQ control structures. Specific contributions included: coordinated EGR-VNT-BYPASS actuation (patented algorithms and modeling for coordinated control during transients of EGR and two-stage turbocharger units with bypass); fast EGR estimator (developed accurate EGR estimation based on oxygen sensors); developed injection timing compensator for enhanced combustion control over transients.

Engineer, Advanced Technologies (1997-2001)

Responsible for Variable Displacement (inlet throttle) fuel injection pump development: Contributed to design of flow and pressure control valve with simulation and testing on bench and on engine. Worked with valve (INVENSYS) and pump (SHEPPARD) manufacturers to deliver product to the I6 and V8 engine lines.

Design of a direct throttle control to optimize flow losses incurred in the pressure regulator. Implemented design in pump and demonstrated performance improvements in bench. Special control system was developed to apply this to fast transients to match performance response to the fast acting pressure regulator.

Lead design for Variable Valve actuation Program - Navistar's Camless engine. Responsible for extensive design, benchmarking, electronic interface, prototype procurement and engine implementation.

APTEK-Air Force Contract Work, Colorado Springs — 1996

Design engineer for Air Force flight control project

Designed wind tunnel imaging and contros to capture turbulent effects on lift-reduction on aircraft.

AWARDS

Stefano Excellence Capstone Design Award for "A Microcomputer-Interfaced Steam Turbine Test Stand", 1990.
Distinguished Paper-Presentation "Effect of Variable Valve Timing on Combustion Characteristics", SAE 2010.

TEACHING

Lecturer of Graduate Level **Fundamentals of Combustion** at the Illinois Institute of Technology.
SAE instructor C1332 "**Variable Valve Actuation: Design and Performance Impact on Advanced Powertrains**"
Instructor Speaker at the University of Toronto NSERC CREATE **Clean Combustion Engines Summer School**.

PROFESSIONAL AFFILIATIONS AND REGISTRATION

Member of the SAE, ASME
Licensed Professional Engineer from the Sate of Illinois no. 062-053677
Designing On-Board Diagnostics for Light and MD Emissions Control Systems, SAE Course Mastered, 2014

PATENTS

US2014/0053811	**System and method of controlling combustion in an engine having an in-cylinder pressure sensor**, W de Ojeda, Raul Espinosa, 27 Feb 2014.
US2013/0218439	**Controlling Variable Valve Actuation System**, Raj Kumar, W de Ojeda, James Popp, Daniel Cornelius, 22 Aug 2013
US2013/0213352	**Start of Injection timing**, Raj Kumar, W de Ojeda, I Sagalovich, 22 Aug 2013
US2012/022857	**Multi-fuel engine with variable valve timing**, W de Ojeda, I Sagalovich, 27 Jan 2013
US2011/0079008	**Strategy for Control of Recirculated Exhaust Gas to Null Turbocharger Boost Error**, 7 April 2011, W de Ojeda, J Popp
US no. 8,069,828	**Intake Valve Closing Hydraulic Adjuster**, 6 Dec 2011, W de Ojeda, Daniel Cornelius
US no. 7,184,877	**Model-Based Controller for Auto-Ignition Optimization in a Diesel Engine**, 27 Feb 2007, W de Ojeda
US no. 7,168,396	**Variable Compression Ratio Strategy for Improving Combustion Processes in Alternative Combustion Compression Ignition engines**, 30 Jan 2007, T. R. Bulicz, X. Gui, W de Ojeda
US no. 7,013,212	**Air Management Strategy for Autoignition in a CI Engine**, 14 March 2006, W de Ojeda, X Yang
US no. 7,004,123	**Unit Trigger Actuator**, W de Ojeda, 28 February 2006
US no. 6,786,186	**Unit Trigger Actuator**, W de Ojeda, 7 September 2004
US no. 6,763,790	**Poppet Valve Actuator**, J.P. Watson and W de Ojeda, 20 July 2004
US no. 6,681,743	**Pressure Control Valve with Flow Recovery**, W de Ojeda, 27 Jan. 2004
US no. 6,338,320	**Hydraulically-assisted engine valve actuator**, W de Ojeda, 15 Jan. 2002
US no. 6,263,842	**Hydraulically-assisted engine valve actuator**, W de Ojeda, P. Das, 24 July 2001
US no. 6,044,815	**Hydraulically-assisted engine valve actuator**, W de Ojeda, 4 April 2000

Selected Publications

1. "Impact of Fuel Cetane Number on Combustion of a Gasoline-Diesel Dual-Fuel Heavy-Duty Multi-Cylinder Engine", Andrew Ickes, Thomas Wallner, Yu Zhang, **William de Ojeda**, 2014-0101309, SAE 2014 World Congress and Exhibition.

2. "Development of Dual-Fuel Low Temperature Combustion Strategy in a Multi-Cylinder Heavy-Duty Compression Ignition Engine Using Conventional and Alternative Fuels", Yu Zhang, Ilya Sagalovich, **William De Ojeda**, Andrew Ickes, Thomas Wallner, David D. Wickman, 2013-01-2422, SAE 2013 Commercial Vehicle Engineering Congress, Chicago.

3. "Ignition Control of Gasoline-Diesel Dual Fuel Combustion", Xiaoye Han, Kelvin Xie, Ming Zheng, **William de Ojeda**, 2012-01-1972, SAE 2012 Commercial Vehicle Engineering Congress, Chicago.

4. "Engine Technologies for Clean and High Efficiency Heavy Duty Engines", **William de Ojeda**, Raj Kumar, 2012-01-1976, SAE 2012 Commercial Vehicle Engineering Congress, Chicago.

5. “Computational Study of Combustion Optimization in a Heavy-Duty Diesel Engine Using In-Cylinder Blending of Gasoline and Diesel Fuels”, Yu Zhang, **William de Ojeda**, David Wickman, 2012-01-1977, SAE 2012 Commercial Vehicle Engineering Congress, Chicago.

6. “A High Efficiency, Dilute Gasoline Engine for the Heavy-Duty Market”, Shinhyuk Michael Joo, Terrence Alger, Christopher Chadwell, **William de Ojeda**, Jacob Zuehl, Raphael Gukelberger, 2012-01-1979, SAE 2012 Commercial Vehicle Engineering Congress, Chicago.

7. "Exhaust Hydrocarbon Speciation from a Single-Cylinder Compression Ignition Engine Operating with In-Cylinder Blending of Gasoline and Diesel Fuels", **William De Ojeda**, Yu Zhang, Kelvin Xie, Xiaoye Han, Meiping Wang, Ming Zheng, 2012-01-0683, SAE 2012 World Congress and Exhibition.

8. “The Impact of Fuel Properties on Diesel Low Temperature Combustion”, **William de Ojeda**, Tytus Bulicz, Xiaoye Han, Kelvin Xie, and Ming Zheng , Fred Cornforth, 2011-01-0329, SAE 2011 World Congress and Exhibition.

9. “The Impact of Fuel Properties on Diesel Low Temperature Combustion”, **William de Ojeda**, Tytus Bulicz, Xiaoye Han, Kelvin Xie, and Ming Zheng , Fred Cornforth, 2011-01-0329, SAE 2011 World Congress and Exhibition.

10. “Effect of Variable Valve Timing on Low-Load Diesel Combustion Characteristics”, **William de Ojeda**, Dan Cornelius, 2010-01-1124, SAE 2010 World Congress and Exhibition.

11. “Development of a Fuel Injection Strategy for Partially Premixed Compression Ignition Combustion”, **William de Ojeda**, Philip Zoldak, Raul Espinosa, Raj Kumar, 2009-01-1527, SAE 2009 World Congress and Exhibition.

12. “Development of a Fuel Injection Strategy for Diesel LTC”, **William de Ojeda**, Phil Zoldak, Raul Espinosa, Raj Kumar, 2008-01-0057, SAE 2008 World Congress and Exhibition

13. “Design of a Model Based Controller for Regulation of Autoignition”, **William de Ojeda**, IMECE2005-80594, ASME 2005 Congress, November 5-11, Orlando, FL.

14. “An Electronic Controlled Throttle for Torque and Stability Optimization in a Fuel Injection Pump”, **William de Ojeda** and Christer Fjellgren, FEDSM2005-77003, ASME Fluids Congress, June 19-23, Houston, TX.

15. “Stability of a Pressure Compensated Circuit for an Inlet Throttled Pump”, **William de Ojeda** and Arturo Hernández, FEDSM2005-77086, ASME Fluids Congress, June 19-23, Houston, TX.

16. “The Needle Valve Actuator”, **William de Ojeda** and Jorge Fernández, IMECE 2003-43607 Congress, Washington DC.

17. “A Microcomputer-Interfaced Steam Turbine Test Stand for an Undergraduate Thermo/Fluids Laboratory”, Joel Hollenberg and **William de Ojeda**, 1990 ASEE Annual Conference, Toronto, Canada.

Journal Publications

1. "Impact of Cetane Number on Combustion of a Gasoline-Diesel Dual-Fuel Heavy-Duty Multi-Cylinder Engine," Ickes, A., Wallner, T., Zhang, Y., and **de Ojeda, W.**, *SAE Int. J. Engines* 7(2): 2014.

2. "Development of Dual-Fuel Low Temperature Combustion Strategy in a Multi-Cylinder Heavy-Duty Compression Ignition Engine Using Conventional and Alternative Fuels," Zhang, Y., Sagalovich, I., **de Ojeda, W**., Ickes, A. et al., SAE Int. J. Engines 6(3): 2013

3. “Emission and Ignition Control for a Gasoline Diesel Dual Fuel Engine”, Submitted to the Journal of Energy Research, 2013, X Han, K Xie, W de Ojeda, M Zheng

4. “Engine Technologies for Clean and High Efficiency Heavy Duty Engines”, **W de Ojeda**, R Kumar, SAE Int .J. Engines 5(4) 1759-1767: 2012

5. “A High Efficiency, Dilute Gasoline Engine for the Heavy-Duty Market”, Shinhyuk Michael Joo, Terrence Alger, Christopher Chadwell, William de Ojeda, Jacob Zuehl, Raphael Gukelberger, 2012-01-1979, SAE Int. J. Engines 5 (4) 1768-1789: 2012

6. "The Impact of Fuel Properties on Diesel Low Temperature Combustion", **William de Ojeda**, Tytus Bulicz, Xiaoye Han, Kelvin Xie, and Ming Zheng , Fred Cornforth, 2011-01-0329, SAE Int. J. Engines June 2011 4:188-201

7. "Development of a Fuel Injection Strategy for Partially Premixed Compression Ignition Combustion", **William de Ojeda**, Philip Zoldak, Raul Espinosa, Raj Kumar, SAE Int. J. Engines October 2009 2:1473-1488.

8. "Hydraulic Flow Compensator for Fast Switch Device", William de Ojeda and Francisco Ruiz, ASME Journal of Dynamics, Systems, Measurements and Controls, Vol. 125, pp. 509–514, September 2003

Conferences and Guest Speaker Events

1. "High-pressure Oil Intensified DME Fuel Injection System Development for Engine-Conditions Spray Combustion", **6th International DME Conference,** San Diego, 7-9 October 2014

2. "Critical Research Needs Relevant to Field of Heavy-Duty Engine Combustion", **Advanced Engine Concepts MOU meeting at the SANDIA CRF**, February 2-7, 2013

3. "Development and Demonstration of a Fuel-Efficient HD Engine (Dept of Energy Supertruck Program)", **DOE DEER CONFERENCE**, October 16, 2012, Dearborn, Michigan.

4. "DOE Supertruck Program: High Efficiency Engine Technologies with Emphasis on Heat Transfer Systems and Components", **NARSA Heavy Duty Heating and Cooling Conference**, Ann Arbor, MI, Sep 20-22, 2012.

5. "IC Engine System Technologies for High Efficiency Heavy Duty Vehicles" Guest Speaker at **SAE Heavy Duty Vehicle Symposium**, Troy, Michigan, 30 Nov 2011.

6. "Development and Demonstration of a Fuel-Efficient HD Engine (Dept of Energy Supertruck Program)", **DOE DEER CONFERENCE**, October 3, 2011, Detroit, Michigan.

7. "Impact of Variable Valve Timing on Low Temperature Combustion", **DOE DEER CONFERENCE**, September 27-30, 2010, Detroit, Michigan

8. "Low Temperature Combustion Demonstrator for High Efficiency Clean Combustion", **DOE DEER CONFERENCE,** Dearborn, Michigan, August 3-6, 2009

9. "Low Temperature Combustion Demonstrator for High Efficiency Clean Combustion", **DOE DEER CONFERENCE**, 26 Feb 2008

10. "Development of a Multi-Cylinder Diesel Engine for HCCI Operation", **Homogeneous Charge Compression Ignition Symposium**, Sep 24-26 2006, San Ramon, California

11. "Performance of an Inlet Throttle Diesel Fuel Injection Pump", **SICFP Congress**, 2005, June 1-3, Linköping, Sweden.

Other Background

- Mentor at Midtown Center for high school students (1992-2009) and at Darien Center (2010-present).
- Founder - Commodore of the Illinois Institute of Technology Sailing Club.
- Fluent in speaking and writing Spanish and some skill in German.

M.J. Bradley & Associates LLC

Dana M. Lowell

Senior Vice President & Technical Director

Dana has worked in MJB&A's advanced vehicle technology group since 2004, providing strategic analysis, project management, and technical support to mobile source emissions reduction programs. His mobile source project work includes evaluation and implementation of advanced diesel emissions controls, alternative fuels, and advanced hybrid and fuel cell electric drives, as well as development and implementation of diesel emissions testing programs for a range of onroad and nonroad heavy-duty vehicle types. Dana brings to clients a wealth of practical knowledge and experience, the real-world perspective of a major fleet operator, and a proven track record in technology implementation.

Dana has 25 years professional experience in the transportation and government sectors. Prior to joining MJB&A, Dana spent seven years as the Assistant Chief Maintenance Officer for Research & Development at MTA New York City Transit's Department of Buses. In his role with NYC Transit, Dana was responsible for both evaluation and implementation of clean fuel technology programs, including technology and vehicle testing, emissions testing and fleet emissions modeling, component/vehicle specification, maintenance program analysis, applications engineering support, financial analysis, budget development and planning, procurement support, and project management. Under his leadership, NYC Transit developed and executed an aggressive program to implement new technologies fleet-wide, resulting in the creation of NYC Transit's Clean Fuel Bus Program to reduce exhaust emissions from the fleet of 4,500 fixed-route transit buses.

Areas of Expertise

- Advanced vehicle emissions reduction technologies
- Vehicle technology development and deployment
- Transit maintenance management
- Vehicle emissions testing
- Diesel inspection and maintenance programs
- Transit vehicle specification and procurement support
- Life cycle cost modeling and financial analysis
- Project management

A recognized electric drive and clean fuel expert within transit, Dana has made numerous presentations at industry conferences and workshops sponsored by APTA, TRB, SAE, US EPA, the Canadian Urban Transit Association, the Electric Power Research Institute, the National Parks Service and the World Bank. He has also served on advisory committees for the Harvard Center for Risk Analysis and the US EPA's Environmental Technology Verification Program.

Representative MJB&A Projects

- NYPA Fleet Analysis – Options to Reduce GHG Emissions
- EDF/Ceres, Effect of EPA Phase 2 Fuel Efficiency Regulations on Freight Rates
- Comparison of Fuel Economy & Emissions from Modern Diesel, CNG, and Hybrid Buses

- Federal Motor Carrier Safety Administration, Recommended Updates to Safety Regulations to Accommodate Electric Drive Vehicles
- Federal Motor Carrier Safety Administration, Training Program for Commercial Vehicle
- Inspectors in Detecting Fuel Leaks from CNG, LNG, and LPG Vehicles
- Port Authority of Allegheny County Bus Fleet Emissions Analysis
- BAE Systems, Hybrid Bus Fuel Economy Testing
- New York City Business Integrity Commission, Analysis of “Age-out” Policy Options to Reduce
- Emissions form Commercial Refuse Trucks in New York City
- Environmental Defense Fund, Policy Options to Reduce Fugitive Emissions from Natural Gas Production Facilities
- ICCT, Policies to Address Electric Vehicle-Grid Integration
- ICCT, Evaluation of Methane Leakage from LNG Marine Fuel Bunkering
- Clean Air Task Force, Diesel Emissions Reduction Policy Toolkits
- Clean Air Task Force, Diesel Black Carbon Climate Comparisons
- New York Power Authority, Hybrid School Bus Demonstration Program
- Federal Motor Carrier Safety Administration, Recommended Updates to Safety Regulations to Accommodate Natural Gas Vehicles
- Regulatory Support to Heavy-duty Diesel Engine Manufacturers for Transition from EPA Tier 2 to EPA Tier 3/4 Regulations
- BAE Systems, Technical Marketing Support and Analysis for Sales of Hybrid-Electric Transit Buses
- Federal Motor Carrier Safety Administration, Guidelines for The Use of Hydrogen Fuel in Commercial Vehicles
- ICCT, Analysis of Trailer Technologies Available to Increase Freight Vehicle Efficiency
- American Clean Skies Foundation, Natural Gas for Marine Vessels, U.S. Market Opportunities
- American Bus Association, Comparison of Coach Bus Service to Amtrak and to the Essential Air Service Program
- ICCT, Policy Options to Address Urban Off-Cycle NOx Emissions from Euro IV/V Trucks
- Chelsea Collaborative, TRU Electrification at New England Produce Center
- Volpe Transportation Center, Fuel Cell Bus Life Cycle Cost Model
- Volpe Transportation Center, Fuel Cell Bus Maintenance Manual & Training Program
- New York Power Authority, Green Fleet Options Analysis
- Clean Air Task Force, Technical Support for Diesel Emission Reduction Policy Development
- Great Lakes Towing, Emissions Testing of SCR-equipped Marine Power Barge
- Conservation Law Foundation, Review of Massachusetts Policies to Reduce GHG from the Transportation Sector
- ICCT, Support for Heavy-Duty Vehicle Fuel Economy/GHG Regulation
- American Lung Association, Technical Support for Energy Policy Development
- CSX, Gen-set Locomotive Emissions Testing
- Keyspan Energy Delivery, Current and Proposed Transportation Technology Review
- Environment Canada, Oil Sands Sector Emission Reduction Feasibility Study
- Translink/GVTA, Bus Technology Demonstration Program, Phase 1, 2, 3 & 4
- Massachusetts Bay Transportation Authority (MBTA), In-service CNG Bus Test Program
- MBTA, Development of an Enhanced Bus Emissions Monitoring and Control Program
- American Bus Association, Transit Modes & GHG Offset Analysis

- Nicholas Institute, BEST BUS Life Cycle Cost and Emissions Model
- PANYNJ, Brooklyn Cruise Terminal Shore Power Feasibility Study
- Massachusetts Department of Environmental Protection, Diesel Engine Retrofits in the Construction Industry: A How to Guide
- STAPPA/ALAPCO, Guidance for the Control of Fine Particulate Matter Emissions from Industry Sectors
- ESP, U.S./Mexican Border Remote Sensing Emissions Testing Project
- Environmental Defense, New York City Idling Emissions Calculator
- NRDC, MTA New York City Transit Bus Fleet Emissions Analysis
- NESCAUM, Region 1 and Region 2 Marine Engine Repower Project
- Northeast Utility Truck Retrofit Program

Prior Work Experience

July 1996 – May 2004	MTA New York City Transit, Department of Buses *Assistant Chief Maintenance Officer, Research & Development*
March 1993 – June 1996	MTA New York City Transit, Dept. of Capital Programs *Manager of Capital Investment Analysis*
Feb 1990 - Feb 1993	City of New York, Office of Management and Budget *Supervising Project Manager, Value Engineering*
Sept 1985 – Sept 1989	United States Army, 299th Engineer Battalion *Battalion Adjutant; Combat Engineer Platoon Leader*

Education

Leonard N. Stern School of Business, New York University, New York, NY

Masters of Business Administration; co-major in Management and Operations Management, 1995
Mayor's Graduate Scholarship; Dean's Award for Academic Excellence

Princeton University, Princeton, NJ

Bachelor of Science in Mechanical Engineering, 1985
Summa Cum Laude; Phi Beta Kappa; Tau Beta Pi
Four-year R.O.T.C. scholarship; Distinguished Military Graduate

Professional Activities

- NESCAUM/MassDEP training on short-lived climate forcers, 2010
- Massachusetts Department of Environmental Protection and MASS Highway diesel retrofit training, 2008
- Chair of Hybrid Bus Working Group, Electric Bus Subcommittee; American Public Transit Association, September 1999 – May 2003

- Member, Technical Advisory Panel for Project C-10 - Transit Bus Technology Related Research; Transit Cooperative Research Program
- Member, Technical Council; Transit Standards Consortium, November 2000 – December 2002
- Member, Technical Screening Committee, FY 2000 Research Program; Transportation Research Board
- Organizer and Session Chair, SAE TOPTEC: Hybrid Electric Vehicles in the Bus & Truck Markets; SAE International, New York, NY, May 2000
- Panelist, Alternative Fuels CUTRcast web-panel session; Center for Urban Transportation Research, July 2000; www.nctr.usf.edu/netcast/altfuels.htm
- Member, Technical Review Panel; U.S. Environmental Protection Agency Environmental Technology Verification Program, November 2000
- Member, Advisory Panel on Alternative Propulsion Technologies; Harvard Center for Risk Analysis, October 1999
- Trainer on alternative fuel technologies; National Park Service Training Session on Alternative Transportation Systems, Philadelphia, PA, November 1999
- Member, Peer Review Panel, South Boston Piers Area Transit Way, Massachusetts Bay Transportation Authority, Boston, MA
- Member, Clean Propulsion & Support Technology Committee, American Public
- Transportation Association

Conference Presentations

- International Association of Ports and Harbors Conference, IAPH 2013
- ICCT International Workshop on Reducing Air Emissions from Shipping, Shanghai, China, 2012
- IUAPPA, World Clean Air Congress, 2010
- Transportation Research Board Annual Meeting, 2006
- World Resources Institute/USAID Workshop on Coupling GHG Reductions with Transport & Local Emissions Management, 2005
- World Bank Training Session on Diesel Pollution, 2004
- World Bank Clean Air Initiative – Diesel Days, Washington DC, January 2003
- Philadelphia Diesel Difference Conference, Philadelphia, PA, May 2003
- Diesel Engine Emissions Reduction (DEER) Conference, US Department of Energy, Newport, RI, August 2003
- EPA-NESCAUM Diesel Retrofit Workshop, New York, NY, October 2003
- SAE Truck and Bus Meeting, November, 2003
- Better Air Quality for Asia Workshop (BAQ 2003), World Bank, Manila, Philippines, December 2003 – video presentation
- Transportation Research Board, 2002 Annual meeting, January 2002
- APTA 2002 Bus & ParaTransit Conference, American Public Transit Association, May 2002
- EESI/NESEA Congressional Briefing on Cleaner Transportation Technologies, Washington, DC, May 2002
- APTA 2001 Bus & ParaTransit Conference, American Public Transit Association, May 2001
- CUTA Annual Conference, Canadian Urban Transportation Association, June 2001
- World Bank Clean Air Initiative Workshop for Lima and Callao, Lima, Peru, July 2001

- World Bus and Clean Fuel Expo 2001, August 2001
- North East Sustainable Energy Association (NESEA), Energizing Schools 2001 Conference, October 2001
- SAE Truck and Bus Meeting, November, 2001
- Transportation Research Board, 2000 Annual meeting, January 2000
- APTA 2000 Bus & ParaTransit Conference, American Public Transit Association, May 2000
- Electric Bus Users Group Workshop, Electric Power Research Institute, March 2000
- Diesel Emissions Control Retrofit Workshop, Corning Inc., March 2000
- Board of Directors Alternative Fuels Workshop, Washington Metropolitan Area Transit Authority, July 2000
- SAE Hybrid Electric Vehicles TOPTEC, May 1999
- Bus Technology & Management Conference, American Public Transit Association, May 1998
- NAEVI 98, North American EV & Infrastructure Conference and Exposition, December 1998

Publications

- Lowell, D., Seamonds, D., "Coming Soon To a Fleet Near You: EPA/NHTSA Fuel Efficiency and GHG Standards For Medium- and Heavy-Duty Trucks", Environmental Energy Insights, May 2014
- Lowell, D., "Short-term Climate Impact of Diesel Emission Reduction Projects", Clean Air Task Force, December 2013 "Comparison of Modern CNG, Diesel and Diesel Hybrid-Electric Transit Buses: Efficiency & Environmental Performance", November 2013
- Lowell, D., "Port Authority of Allegheny County Bus Fleet Emissions 2005 – 2019", Pittsburgh Foundation, October 2013
- Lowell, D., Seamonds, D., "New York City Commercial Refuse Truck Age-out Analysis", Environmental Defense Fund and New York City Business Integrity Commission, September 2013
- Wang, H., Lutsey, N., Lowell, D., "Consideration of the Lifecycle Greenhouse Gas Benefit from Liquefied Natural Gas as an Alternative Marine Fuel", submitted to International Maritime Organization, Sub-committee on Bulk Liquids and Gas by Institute of Marine Engineering, Science and Technology (IMarEST), October 2013
- Lowell, D., "NYPA Hybrid Electric School Bus Evaluation Project, Phase 2 FINAL REPORT", New York Power Authority, September 2013
- Whitman, A., Lowell, D., Balon, T., "Electric Vehicle Grid Integration in the U.S., Europe, and China: Challenges and Choices for Electricity and Transportation Policy", International Council on Clean Transportation and Regulatory Assistance Project, July 2013
- Lowell, D. and Seamonds, D., "Supporting Passenger Mobility and Choice by Breaking Modal Stovepipes: Comparing Amtrak and Motor Coach Service", July 2013, American Bus Association Foundation
- Sharpe, B., Clark, N. and Lowell, D., "Trailer Technologies for increased heavy-duty vehicle efficiency: technical, market, and policy considerations", White Paper, International Council on Clean Transportation, June 2013
- Lowell, D., FMCSA-RRT-13-044, "Natural Gas Systems: Suggested Changes to Truck and Motor Coach Regulations and Inspection Procedures", Federal Motor Carrier Safety Administration, March 2013

- Lowell, D., Balon, T., Van Atten, C., Curry, T., Hoffman-Andrews, L., “Natural Gas for Marine Vessels: U.S. Market Opportunities”, American Clean Skies Foundation, 2012
- Sharpe, B., Lowell, D., “Certification Procedures for Advanced Technology Heavy-Duty Vehicles: Evaluating Test Methods and Opportunities for Global Alignment”, SAE International, SAE 201201-1986, 2012
- Lowell, D., “Clean diesel versus CNG buses: Cost, air quality, & climate impacts”, Clean Air Task Force http://www.catf.us/resources/publications/files/20120227Diesel_vs_CNg_FINAL_MJBA.pdf, 2012
- Lowell, D. and Kamaketé, F., “Urban off-cycle NOX emissions from Euro IV/V trucks and buses: Problems and solutions for Europe and developing countries”, White Paper No. 18, International Council on Clean Transportation, march 2012, http://www.theicct.org/urbancycle-nox-emissions-euro-ivv-trucks-and-buses
- Moynihan, P., Balon, B., Lowell, D., “NESCAUM Region 2 Marine Ferry and Tug Repower Project FINAL REPORT”, NESCAUM, 2011
- Bongiovanni, R., “Chelsea Collaborative New England Produce Center TRU Electrification FINAL REPORT”, Chelsea Collaborative, 2011
- Lowell, D., Seamonds, D., “Alternative Fueled Fleet Vehicle Analysis”, Electric Power Research institute, EPRI 1023045, 2011
- Lowell, D., Curry, T., Hoffman-Andrews, L., Reynolds, L., “Comparison of Essential Air Service Program to Alternative Coach Bus Service: Keeping Rural Communities Connected”, American Bus Association Foundation, September 2011
- Lowell, D., Balon, T., Danos, T., “Bus Technology & Alternative Fuels Demonstration Project Phase 4 Final Report”, Greater Vancouver Transportation Authority, 2011
- Balon, T., Clark, N., Moynihan, P., Lowell, D., “Development of a Combined Oxidation System and Seawater Scrubber to Reduce Diesel NOx Emissions from Marine Engines Final Report”, Houston Advanced Research Center, New Technology Research & Development Program N-40, 2011
- Balon, T., Moynihan, P., Lowell, D., Danos, T., Seamonds, D., “CSX Genset Switcher#1317 Locomotive Emission Testing FINAL REPORT”, NESCAUM, 2010
- Park, D, Curry, T, Lowell, D., Balon, T.H., Piper, S, “Implications of Introducing Hydrogen Enriched Natural Gas in Gas Turbines”, Atlantic Hydrogen, Inc, January 2010
- Lowell, D., Balon, T., Seamonds, D., Leigh, R., Silverman, I., “The Bottom of the Barrel: How the Dirtiest Heating Oil Pollutes Our Air and Harms Our Health”, Environment Defense Fund, 2009
- Posada, F., Lowell, D. (editor), “CNG Bus Emissions Roadmap: from Euro III to Euro VI”, international Council on Clean Transportation, 2009
- Lowell, D., “Lower Manhattan Construction, Construction Equipment Retrofit Case Study”, Clean Air Task Force, 2009
- Lowell, D., Seamonds, D.G., “Evaluation of Vehicle Emissions Reduction Options for the Oil Sands Fleet”, Environment Canada, March 2008
- Lowell, D., Balon, T.H., “Setting the Stage for Regulation of Heavy-Duty Vehicle Fuel Economy & GHG Emissions: Issues and Opportunities,” International Council on Clean Transportation, March 2008
- Lowell, D., Balon, T. H., Danos, T. J., Moynihan, P.J., “Diesel Engine Retrofits in the Construction Industry: A How To Guide”, Massachusetts Department of Environmental Protection, January 2008.
- Lowell, D., Balon, T., “Brooklyn Cruise Terminal Shore Power Feasibility Analysis”, Port Authority of New York and New Jersey, 2008
- Johnson, P., Graham, J., Amar, P., Cooper, C., Skelton, E., Lowell, D., Van Atten, C., Berwick, A., “Assessment of Carbonaceous $PM_{2.5}$ for New York and the Region”, New York State Energy Research & Development Authority, NYSERDA Report 08-01, 2008

- Lowell, D., "Guidelines for Use of Hydrogen Fuel in Commercial Vehicles: Final Report", US Department of Transportation, November 2007.
- "Comparison of Energy Use & CO2 Emissions from Different Transportation Modes", American Bus Association, May 2007.
- Lowell, D., Chernicoff, W., Lian, F., "Fuel Cell Bus Life Cycle Cost Model: Base Case & Future Scenario Analysis", U.S. Department of Transportation, DOT-T-07-01, June 2007
- Balon**,** T.H., Lowell, D., Moynihan, P.J., Wilensky, L.S., Piper, S.G., Danos, T.J., Hamel, C.J., "Staten Island Ferry Alice Austen Vessel SCR Demonstration Project Final Report," Port Authority of New York and New Jersey, August 2006.
- Berwick, A., Bradley, M., Van Atten C., Lowell, D., Curry, T., Durbin, D., "Controlling Fine Particulate Matter under the Clean Air Act: A Menu of Options", STAPPA/ALAPCO, 2006
- Lowell, D., "Life Cycle Cost & Emissions Model Alternative Bus Technologies; Final Report", Nicholas Institute for Environmental Policy Solutions, 2006
- Lowell, D., Balon, T., Grumet, S., Vescio, N., Full, G., Fraser, J., McClintock, P., "Cross Border InUse Emissions Study for Heavy Duty Vehicles, Nogales, AZ FINAL REPORT", Arizona Department of Environmental Quality and US Environmental Protection Agency, 2006
- Bauer-Darr, L., Buchanon, B., Jack, J., Lowell, D., Shitres, C., "Commercial Bus Emissions & Fuel Use: Idling versus Urban Circulator", Transportation Research Board, 2006
- Lowell, D., Balon T., "Natural Gas as a Transportation Fuel: Best Practices for Achieving Optimal Emissions Reductions", International Council on Clean Transportation discussion paper, 2005
- Lowell, D., Balon, T.H., Wilensky, L.S., Moynihan, P.J., Drew, S.J., Kerr, L, "Local Law 77: DDC UltraLow Sulfur Diesel Manual," City of New York Department of Design and Construction, June 2004.
- Beregszasky, C., Bush, C., Chatterjee, S., Conway, R., Evans, J., Frank, B., Lanni, T., Lowell, D., Meyer, N., Rideout, G., Tang, S., Windawi, H., "SAE 2004-01-1085, A study of the Effects of Fuel Type and Emissions Control System on Regulated Gaseous Emissions from Heavy Duty Diesel Engines", Society of Automotive Engineers, 2004
- Frank, B., Lanni, T., Lowell, D., Rosenblatt, D., Tang, S., "SAE 2003-01-0300, Evaluation of Compressed Natural Gas and Clean Diesel Buses at New York City's Metropolitan Transportation Authority", Society of Automotive Engineers, 2003
- Bush, C., Lowell, D., Parsley, W., Zupo, D., "A Comparison of Clean Diesel Buses to CNG Buses", Diesel Engine Emissions Reduction (DEER) Conference, US Department of Energy, Newport, RI, August 2003
- Bush, C., Chatterjee, S., Conway, R., Evans, J., Frank, B., Lanni, T., Levy, S., Lowell, D., Mclean, R., Rosenblatt, D., Tang, S., "SAE 2002-01-0430, Performance and Durability Evaluation of Continuously Regenerating Particulate Filters on Diesel Powered Urban Buses at NY City Transit – Part II", Society of Automotive Engineers, 2002
- Lowell, D. "Clean Diesel: Fact or Fiction", BusTech Magazine, Summer 2001
- Bush, C., Chatterjee, S., Conway, R., Evans, J., Lanni, T., Lowell, D., Mclean, R., Rosenblatt, D., Windawi, H, "SAE 2001-01-0511, Performance and Durability Evaluation of Continuously Regenerating Particulate Filters on Diesel Powered Urban Buses at NY City Transit", Society of Automotive Engineers, 2001
- Lowell, D. "NYC Transit Shares Tricks of Maintaining Hybrids", BusTech Magazine, Summer 2000

CURRICULUM VITAE

SHAWN W. MIDLAM-MOHLER, PH.D., P.E., P.M.P.
930 Kinnear Road
Columbus, Ohio 43212
(614) 307-4176
midlam-mohler.1@osu.edu

CURRENT APPOINTMENTS

Assistant Professor of Practice – Primary Appointment 8/2012 to present
Ohio State University Department of Mechanical and Aerospace Engineering, Columbus, OH

Associate Director 1/2014 to present
Ohio State University Simulation Innovation and Modeling Center, Columbus, OH

OSU-CAR Associate Fellow 8/2012 to present
Ohio State University Center for Automotive Research, Columbus, OH

Director of OSU Motorsports 7/2013 to present
Ohio State University College of Engineering, Columbus, OH

PROFESSIONAL EXPERIENCE

Research Scientist 10/2008 to 7/2012
Ohio State University Center for Automotive Research, Columbus, OH

Senior Research Associate 11/2005 to 9/2008
Ohio State University Center for Automotive Research, Columbus, OH

Research Associate II 2/2004 to 10/2005
Ohio State University Center for Automotive Research, Columbus, OH

EDUCATION

Ph.D.	Mechanical Engineering		6/2005
	The Ohio State University	Columbus, OH	
	Dissertation Title: "Modeling, Control, and Diagnosis of a Diesel Lean NO_x Trap Catalyst"		
M.S.	Mechanical Engineering		3/2001
	The Ohio State University	Columbus, OH	
	Thesis Title: "A Novel Fuel-Operated Heater for Automotive Thermal Management"		
B.S.	Mechanical Engineering	*summa cum laude*	6/1999
	Wright State University	Dayton, OH	

PROFESSIONAL LICENSES

Professional Engineer License 75703
State of Ohio

Project Management Professional License 1622962
Project Management Institute

RESEARCH EXPERIENCE

Dr. Midlam-Mohler maintains an active research program focused the area of Model-Based Design of Complex Systems. Research expenditures as PI/co-PI total more than $7 million.

Projects as PI / Co-PI:

Start Date	Duration (Years)	Sponsor	Project Title
8/2005	1.9	Tenneco Automotive	Diesel Particulate Filter Regeneration with External Burner
9/2005	3.3	Tenneco Automotive	Reductant Generation for NOx Remediation
3/2007	0.8	Tenneco Automotive	Heavy duty Burner Prototypes and Control Development
3/2007	3.8	General Motors Corp	Development and implementation of a methodology, processes, and tools to produce a hierarchy of powertrain models that enable a math-based virtual design environment for powertrain control
9/2007	1.6	Nat Energy Tech Lab	Design and Fabrication of Diesel Fuel Atomizers
1/2008	2.0	Tenneco Automotive	Non-Catalytic Reformer Sensitivity Study and Prototype Development
4/2008	4.0	Cummins, Inc	Diesel Engine Combustion Control
9/2008	3.0	Department of Energy / General Motors	EcoCAR 1 Advanced Technology Vehicle Competition
1/2009	3.0	CAR PHEV Consortium	Fleet Studies and Transformer Modeling of PHEVs
4/2009	2.3	FirmGreen, Inc.	Landfill Gas Derived CNG Fuel Cycle Analysis
4/2009	3.4	Cummins, Inc	Cummins CIDI Engine Variability Measurements
4/2009	2.5	Stoneridge	Soot Sensor Testing and Soot Sensor Test Fixture
9/2009	1.3	Henkel Corp	Combustion Chamber Coating Evaluation
5/2010	3.8	Chrysler Group LLC	Advanced Technology Powertrains for Light-Duty Vehicles
10/2010	2.0	CAR Industrial Consortium	Lubricant Effects on Advanced Technology Vehicles
8/2011	3.0	Stoneridge	Fundamental Electrical Properties of Diesel Soot Films on a Diesel Soot Sensor

9/2011	3.0	Department of Energy / General Motors	EcoCAR 2 Advanced Technology Vehicle Competition
8/2012	2.0	Ctr for Trans. & Environment	ECO Saver IV Hybrid Electric Fuel Cell Bus Demonstration
10/2012	2.0	CAR Industrial Consortium	Gasoline Engine Particulate Matter Control
1/2013	0.3	Honda R&D Americas	Automated Vehicle Control using Low-Cost Sensors
7/2013	0.5	American Electric Power	Plug-In Electric Vehicle Data Analyses, Insights and Reports
12/2013	2.0	Chrysler Group LLC	Model-Based Optimization and Control Methodology for the Design of Chrysler's Next Generation Powertrain Control Systems
9/2014	2.0	Honda R&D Americas	Engine Startability Simulation, Modeling, and Control
9/2014	2.0	Honda R&D Americas	Model-Based Engine Calibration Techniques
9/2014	1.7	Chrysler Group LLC	Model-Based Particulate Filter Diagnosis and Control
8/2014	4	Department of Energy / General Motors	EcoCAR 3 Advanced Technology Vehicle Competition

TEACHING EXPERIENCE

Undergraduate and Graduate Courses

Dr. Midlam-Mohler has been involved in classroom education since 2007. His teaching focuses on automotive technical electives, capstone senior design, and most recently a course on project management and systems engineering.

Period Offered	Course Number and Title (Credit Hours)
Spring 2007	ME 730 Internal Combustion Engine Modeling
Winter 2009	ME 631 Automotive Powertrain Laboratory
Spring 2009	ME 730 Internal Combustion Engine Modeling
Winter 2010	ME 631 Automotive Powertrain Laboratory
Winter 2011	ENGR 659.01 Multidisciplinary Capstone 1
Winter 2011	ME 565.02 Mechanical Engineering Design 1
Winter 2011	ME 631 Automotive Powertrain Laboratory
Spring 2011	ENGR 659.02 Multidisciplinary Capstone 2
Spring 2011	ME 565.03 Mechanical Engineering Design 2
Winter 2012	ENGR 659.01 Multidisciplinary Capstone 1
Winter 2012	ME 565.02 Mechanical Engineering Design 1
Winter 2012	ME 631 Automotive Powertrain Laboratory
Spring 2012	ENGR 659.02 Multidisciplinary Capstone 2
Spring 2012	ME 565.03 Mechanical Engineering Design 2
Fall 2012	ME 4902.01 Mechanical Engineering Capstone 1
Spring 2013	ME 4902.02 Mechanical Engineering Capstone 2

Spring 2013	ME 5531 Automotive Powertrain Laboratory
Fall 2013	ME 4902.01 Mechanical Engineering Capstone 1
Fall 2013	ME 4194 Applied Project Management and System Engineering 1 (Pilot)
Spring 2014	ME 4902.02 Mechanical Engineering Capstone 2
Spring 2014	ME 5531 Automotive Powertrain Laboratory
Spring 2014	ME 4194 Applied Project Management and System Engineering 2 (Pilot)
Fall 2014	ME 4902.02 Engineering Capstone
Fall 2014	ME 5194 Applied Project Management and System Engineering 1

Distance Education Courses

Dr. Midlam-Mohler is an active participant in the distance education program provided to General Motors through the Center for Automotive Research. He has also developed a number of courses in his area of expertise for the Department of Energy sponsored advanced technology vehicle competition program.

Internal Combustion Engines from a System Perspective 2014
Ohio State University, Columbus, OH

- Developed a 6 hour seminar from on IC engines from a systems perspective
- Supported by the Department of Energy

IC Engine Modeling 2014
Ohio State University, Columbus, OH

- Developed a 6 hour seminar from on modeling of internal combustion engines
- Supported by the Department of Energy

Matlab for Data Analysis and Calibration Seminar 2013
Ohio State University, Columbus, OH

- Developed a 10 hour seminar on the use of Matlab for data analysis and calibration
- Developed for the CAR Distance Education program

SIL/HIL Techniques for Automotive Control Development 2013
Ohio State University, Columbus, OH

- Developed a 10 hour seminar on the use of software-in-the-loop and hardware-in-the-loop techniques for control code validation and verification
- Developed for the CAR Distance Education program

Model-Based Control of Hybrid Electric Vehicles 2012
Ohio State University, Columbus, OH

- Developed a 6 hour seminar from on model-based control of hybrid vehicles
- Supported by the Department of Energy

Alternative Fuels Seminar 2013
Ohio State University, Columbus, OH

- Developed a 10 hour seminar on automotive alternative fuels
- Developed for the CAR Distance Education program

Community Education

Invited Speaker for Public Events on Energy 2009 - present
Various locations

- Invited speaker on energy and transportation at events such as: Automotive Engineering Career Panel, Charging Forward Conference, Green Energy Ohio, OSU College of Engineering Continuing Education Program, and the Moving Ahead Conference

- Involved in OSU College of Engineering Summer Camps

Speaker for Groups Touring the Ohio State Center for Automotive Research 2007 - present
Ohio State University Center for Automotive Research

- Provide 30 – 60 minute presentation and discussion on topic of energy use in transportation to groups
- Typically speak to >300 people per year on the topic of energy use in transportation

Supervisor for EcoCAR Team Outreach Efforts 2008 - present
Various locations

- Team is evaluated on ability to communicate information on transportation and energy to the general public, K-12 students, and influencers (i.e., industry leaders, government officials)
- Team has won numerous awards for outreach at the EcoCAR competition

Graduate Student Advising and Supervision

Dr. Midlam-Mohler has an active advising history of students earning advanced engineering degrees. This includes students enrolled at Ohio State as well as visiting scholars from outside of the institution.

Doctoral Student (Co-Advisor)

1. 2012 - Present Katherine Bovee. The Ohio State University.
2. 2014 - Present David Hillstrom. The Ohio State University.
3. 2014 - Present Bharat Hegde. The Ohio State University.

Masters Student (Advisor)

1. 2008 - 2009 Ming Fang. The Ohio State University.
2. 2008 - 2009 Rajaram Maringanti. The Ohio State University.
3. 2009 - 2010 Chris Hoops. The Ohio State University.
4. 2009 - 2010 Brad Cooley. The Ohio State University.
5. 2010 - 2011 Beth Bezaire. The Ohio State University.
6. 2010 - 2011 Ryan Everett. The Ohio State University.
7. 2010 - 2011 John Davis. The Ohio State University.
8. 2011 - 2012 Abhay Gupta. The Ohio State University.
9. 2011 - 2013 Andy Garcia. The Ohio State University.
10. 2012 - 2013 Saba Gurusubramanian. The Ohio State University.
11. 2012 - 2013 Teng Ma. The Ohio State University.
12. 2012 - 2013 Nithin Baradwaj. The Ohio State University.
13. 2012 - 2013 Steven Ramirez. The Ohio State University.
14. 2012 - 2014 Matt Organiscak. The Ohio State University.
15. 2012 - 2014 David Hilstrom. The Ohio State University
16. 2012 - 2014 Tamal Mukarjee. The Ohio State University.
17. 2011 - 2014 Amanda Hyde. The Ohio State University.
18. 2012 - 2014 Shreyas Shrivaprasad. The Ohio State University.
19. 2012 - 2014 Eric Gallo. The Ohio State University.
20. 2013 - 2014 David Hillstrom. The Ohio State University.
21. 2013 - 2014 Bharat Hedge. The Ohio State University.
22. 2012 - Present Andrew Spiegal. The Ohio State University.
23. 2013 - Present Benjamin Stumpf. The Ohio State University
24. 2013 - Present Jason Ward. The Ohio State University.
25. 2013 - Present Samuel Yacinthe. The Ohio State University.
26. 2014 - Present Aaron Bonnell-Kangas. The Ohio State University.
27. 2014 - Present Luke Cardinale. The Ohio State University.
28. 2014 - Present James Mack. The Ohio State University.

Masters Student (Co-Advisor)

1. 2004 - 2005 Eric Snyder. The Ohio State University.
2. 2005 - 2006 Courtney Coburn. The Ohio State University.
3. 2005 - 2006 Adam Vosz. The Ohio State University.
4. 2006 - 2007 Josh Cowgill. The Ohio State University.
5. 2006 - 2007 Kenny Follen. The Ohio State University.
6. 2011 - 2012 Katherine Bovee. The Ohio State University.
7. 2011 - 2014 Matt Yard. The Ohio State University.

Undergraduate Research (Advisor)

1. 2006 - 2007 Rhisee Bhatt. The Ohio State University.
2. 2008 - 2009 Chris Hoops. The Ohio State University.
3. 2009 - 2010 Ryan Everett. The Ohio State University.
4. 2009 - 2010 John Davis. The Ohio State University.
5. 2009 - 2010 Katherine Bovee. The Ohio State University.
6. 2012 - 2013 Jason Ward. The Ohio State University.
7. 2012 - 2013 Andrew Speigel. The Ohio State University.
8. 2013 - 2014 MJ Yatsko. The Ohio State University.
9. 2013 - 2014 Gaurav Krishnaraj. The Ohio State University.
10. 2012 - Present Arjun Khanna. The Ohio State University.

Senior Capstone Group Advising

Dr. Midlam-Mohler has been actively involved in the advising of student capstone design projects which typically span 1.5 semesters. In these projects, small groups of students are required to design, build, and test a prototype. In Dr. Midlam-Mohler’s courses, each group works on a different project.

- AY 2011-2012: Four Capstone Groups Advised
- AY 2012-2013: Five Capstone Groups Advised
- AY 2013-2014: Seven Capstone Groups Advised

Student Organization Advising

EcoCAR 2 Hybrid Electric Vehicle Team 7/2011 – 6/2014
Ohio State University, Columbus, OH

- Serve as lead co-adviser of a 40 member (~80% undergraduate) student design project team competing in U.S. Department of Energy sponsored vehicle competition
- Supervised the student-led preparation of the top-ranked proposal for entry into the competition
- The team finished 2nd place in the first year of competition, 3rd place in the second year, and 1st place the final year of the competition

EcoCAR Challenge Hybrid Electric Vehicle Team 6/2008 – 6/2011
Ohio State University, Columbus, OH

- Served as lead co-adviser of a 40 member (~80% undergraduate) student design project team competing in U.S. Department of Energy sponsored vehicle competition
- Team won 1st, 5th, and 2nd in the three years of competition and won numerous event awards

Challenge-X Hybrid Electric Vehicle Team 8/2006 – 6/2008
Ohio State University, Columbus, OH

- Co-advised primarily undergraduate team competing in a U.S. Department of Energy sponsored advanced technology vehicle competition
- Over the course of the four year competition from 2004 – 2008, OSU placed 3rd, 4th, 4th, and 3rd respectively

High School Students Mentoring

Dr. Midlam-Mohler has mentored six local high school students for ~30 hours of activity per student since 2007. These students have been from the Hilliard School District's mentorship program.

INTERNAL SERVICE

Automotive Graduate Specialization Committee Member 2013 to present
Ohio State University, Columbus, OH

- Played lead-role in remapping graduate specialization from quarters to semesters

Graduate Admissions Committee 2012 to present
Ohio State University, Columbus, OH

- On committee which reviews graduate student applications and recommends acceptance to the Department and consideration for Department and University fellowships

CAR Facilities Planning Team Member 2012 to present
Ohio State University, Columbus, OH

- Participate in team dealing with space and facilities issues at the Center for Automotive Research

ME Design Faculty Curriculum Team Member 2011 to present
Ohio State University, Columbus, OH

- Participate in faculty group responsible or capstone design experience in ME

CoE Design Faculty Curriculum Team Member 2011 to present
Ohio State University, Columbus, OH

- Participate in faculty group coordinating the capstone design experience across the College

EXTERNAL SERVICE

EcoCAR 2 Faculty Advisory Board
Board Member 8/2011 to 7/2012 and 8/2013 to present

- Work with EcoCAR 2 competition staff , General Motors staff, and four other EcoCAR 2 team advisors to improve the student design experience for the EcoCAR 2 competition
- Elected to the position by a vote of the EcoCAR 2 faculty advisors

Clean Fuels Ohio, Columbus, OH 9/2009 to 5/2013
Member of the Board of Directors

- Elected to Board of Directors of Clean Fuels Ohio, a non-profit committed to cleaner transportation fuels which is part of the U.S. Department of Energy Clean Cities program
- Served as Secretary and member of the Executive Committee for the organization

Publication Reviewer 2005 to present

- Review numerous publications for conferences and journal submissions to ASME, SAE, IEEE, *etc.*

PAID EXTERNAL CONSULTING

EPA Automotive Technology Policy Report Reviewer, Columbus, OH
Peer Reviewer 6/2012

- Conducted a compensated peer review of a study of future light-duty vehicle technology used in making policy decisions for future fuel-economy regulations.

EPA Light-Duty Vehicle Model Reviewer, Columbus, OH
Peer Reviewer 6/2011

- Conducted a compensated peer review of a study of future light-duty vehicles for the U.S. EPA used for guiding future fuel economy and greenhouse gas emissions regulations

EPA GEM Model Reviewer, Columbus, OH
Peer Reviewer 12/2010

- Conducted a compensated peer review of a heavy-duty truck model developed by the U.S. EPA used for predicting fuel economy and greenhouse gas emissions

State of Indiana 4/2009
Proposal Reviewer

- Reviewed multi-million dollar proposal for Indiana grant program in area of internal combustion engines

McMaster Fuel Ltd., Perrysburg, OH 9/2006 to 1/2007
Independent Consultant

- Provided analysis of a hydrogen production technique against other methods of hydrogen production
- Assisted McMaster Fuel Ltd. in making strategic decisions regarding their technology

AWARDS

Applied Automotive Engineering Fellow - Department of Energy 10/2013

- Presented to a acknowledge significant contributions to applied automotive engineering research and education

Outstanding Technology Team – TechColumbus 2/2012

- Presented to a team of OSU-CAR faculty and research staff because of their extensive partnerships driving technology forward in Ohio

National Science Foundation Outstanding Incoming Faculty Advisor Award 7/2011

- Presented to the junior EcoCAR faculty advisor who best promotes the goals, objectives, and activities related to the EcoCAR student design competition

INTELLECTUAL PROPERTY

1. Rajagopalan, Sai SV, Kenneth P. Dudek, Sharon Liu, Stephen Yurkovich, Shawn W. Midlam-Mohler, Yann G. Guezennec, and Yiran Hu. "Universal tracking air-fuel regulator for internal combustion engines." U.S. Patent 8,571,785, issued October 29, 2013.
2. Midlam-Mohler, S., Meyer, J., Yurkovich, S., & Sujan, V. (2012). U.S. Patent Application 13/479,568
3. J. Meyer, S. Midlam-Mohler, K. Dudek, S. Yurkovich, Y. Guezennec, "Fuel control system and method for more

accurate response to feedback from an exhaust system with an air/fuel equivalence ratio offset”, U.S. Patent 8,347,866, awarded January 8, 2013.

4. S. Midlam-Mohler, S. Rajagoplan, K. Dudek, S. Yurkovich, Y. Guezennec, “Compensating for random catalyst behavior”, 8,346,458, January 1, 2013.
5. J. Meyer, S. Midlam-Mohler, K. Dudek, S. Yurkovich, Y. Guezennec, “Delay calibration systems and methods”, U.S. Patent 8,265,858, awarded September 11, 2012.
6. S. Rajagolalan, J. Meyer, S. Midlam-Mohler, K. Dudek, S. Yurkovich, Y. Guezennec “Control systems and methods using geometry based exhaust mixing model”, U.S. Patent 8,224,557, awarded July 17, 2012.
7. J. Meyer, S. Midlam-Mohler, K. Dudek, S. Yurkovich, Y. Guezennec, “Fuel control system and method for improved response to feedback from an exhaust system”, U.S. Patent 8,186,336, awarded May 29, 2012.
8. J. Meyer, S. Midlam-Mohler, K. Dudek, S. Yurkovich, Y. Guezennec, “Delay compensation systems and methods”, U.S Patent 8,113,187, awarded 2/12/2012.
9. Y. Hu, K. Dudek, S. Midlam-Mohler, Y. Guezennec, S. Yurkovich, L. Wiggins, “System and method for determining a camshaft position in a variable valve timing engine”, U.S. Patent 8,096,271, awarded 1/17/2012.
10. S. Liu, K. Dudek, S. Rajagoplan, S. Yurkovich, Y. Hu, Y. Guezennec, S. Midlam-Mohler, “Off-line calibration of universal tracking air fuel ratio regulators”, U.S. Patent 7,925,421, awarded 4/12/2011.
11. K. Dudek, S. Rajagoplan, S. Yurkovich, Y. Hu, Y. Guezennec, S. Midlam-Mohler, L. Avallone, I. Anilovich, “Air fuel ratio control system for internal combustion engines”, U.S. Patent 7,937,209, awarded 5/3/2011.
12. S. Midlam-Mohler, B. Masterson, "System System for Controlling NOx Emissions during Restarts of Hybrid and Conventional Vehicles,” U.S. Patent 7,257,493, awarded 3/21/07.
13. S. Midlam-Mohler, "System and Method for Reducing NOx Emissions after Fuel Cut-Off Events,” U.S. Patent 7,051,514, awarded 5/30/06.

PUBLICATIONS

Journal Articles

1. Hyde, A., Midlam-Mohler, S., and Rizzoni, G., "Development of a Dynamic Driveline Model for a Parallel-Series PHEV," SAE Int. J. Alt. Power. 3(2):244-256, 2014, doi: 10.4271/2014-01-1920. 2014.
2. Rajagopalan, S. S., Midlam-Mohler, S., Yurkovich, S., Dudek, K. P., Guezennec, Y. G., & Meyer, J. “A control design and calibration reduction methodology for AFR control in gasoline engines”, Control Engineering Practice, 27, 42-53. 2014.
3. Q. Gong, S. Midlam-Mohler, V. Marano, G. Rizzoni, “Statistical Analysis for PHEV Virtual Fleet Study”, International Journal of Vehicle Design, Vol. 58, Nos. 2/3/4, 2012.
4. Gong, Qiuming, Shawn Midlam-Mohler, Vincenzo Marano, and Giorgio Rizzoni. “Virtual PHEV fleet study based on Monte Carlo simulation.” *International Journal of Vehicle Design* 58, no. 2–4 (2012): 266–290. doi:10.1504/IJVD.2012.047388.
5. B. Cooley, D. Vezza, S. Midlam-Mohler, G. Rizzoni, “Model Based Engine Control Development and Hardware-in-the-Loop Testing for the EcoCAR Advanced Vehicle Competition”, SAE International Journal on Engines, Vol. 4, No. 1, pp. 1699 -1707, 2011.
6. Meyer, Jason,A; Yurkovich,Stephen; Midlam-Mohler,Shawn. "A Model Based Estimator for Cylinder Specific Air-to-Fuel Ratio Corrections." JOURNAL OF DYNAMIC SYSTEMS MEASUREMENT AND CONTROL-TRANSACTIONS OF THE ASME. Vol. 133, no. 3. (May 2011): 031001.
7. Q. Gong, S. Midlam-Mohler, V. Marano, G. Rizzoni, “An Iterative Markov Chain Approach for Generating Vehicle Drive Cycles”, SAE International Journal on Engines, Vol. 4, No. 1, pp. 1035-1045, 2011.
8. M. Canova, S. Midlam-Mohler, P. Pisu, A. Soliman, “Model-Based Fault Detection and Isolation for a Diesel Lean NOx Trap Aftertreatment System,” Control Engineering Practice, November 2009.
9. M. Canova, S. Midlam-Mohler, Y. Guezennec, G. Rizzoni, "Mean Value Modeling and Analysis of HCCI Diesel Engines with External Mixture Formation,” ASME Journal of Dynamic Systems, Measurement and Control, Vol. 131, No. 11, 2009.

10. M. Canova, S. Midlam-Mohler, Y. Guezennec, G. Rizzoni, "Theoretical and Experimental Investigation on Diesel HCCI Combustion with External Mixture Preparation," International Journal of Vehicle Dynamics, Volume 44, Nos 1-2, 2007.
11. N. Szabo, C. Lee, J. Trimboli1, O. Figueroa, R. Ramamoorthy, S. Midlam-Mohler, A. Soliman, H. Verweij, P. Dutta and S. Akbar, "Ceramic-Based Chemical Sensors, Probes and Field-Tests in Automobile Engines," Journal of Materials Science, November, 2003.

Conference Papers

1. Bovee, K., Hyde, A., Yatsko, M., Yard, M., Organiscak, M., Gallo, E. ... & Midlam-Mohler, S. W., "Refinement of a Parallel-Series PHEV for Year 3 of the EcoCAR 2 Competition", SAE Technical Paper 2014-01-2908, 2014.
2. Alley, Robert Jesse, Patrick Walsh, Nicole Lambiase, Brian Benoy, Kristen De La Rosa, Douglas Nelson, Shawn Midlam-Mohler, Jerry Ku, and Brian Fabien. "ESS Design Process Overview and Key Outcomes of Year Two of EcoCAR 2: Plugging in to the Future." SAE Technical Paper, 2014.
3. Hyde, Amanda, Shawn Midlam-Mohler, and Giorgio Rizzoni. "Development of a Dynamic Driveline Model for a Parallel-Series PHEV." SAE Technical Paper, 2014.
4. Bovee, K., Hyde, A., Yard, M., Gallo, E., Garcia, A., Organiscak, M., Midlam-Mohler, S. W. & Rizzoni, G., "Fabrication of a Parallel-Series PHEV for the EcoCAR 2 Competition" ,SAE Technical Paper 2013-01-2491, 2013.
5. Gong, Q., S. Midlam-Mohler, E. Serra, V. Marano, and G. Rizzoni. "PEV charging control for a parking lot based on queuing theory." In *American Control Conference (ACC), 2013*, pp. 1124-1129. IEEE, 2013.
6. Meyer, Jason, Stephen Yurkovich, and Shawn Midlam-Mohler. "Air-to-Fuel Ratio Switching Frequency Control for Gasoline Engines." In *Control Systems Technology, IEEE Transactions on*, 21:636–48, 2013.
7. Bezaire, Beth, and Shawn Midlam-Mohler. "A Physically-Based, Lumped-Parameter Model of an Electrically-Heated Three-Way Catalytic Converter." SAE Technical Paper, 2012.
8. Bovee, Katherine, Amanda Hyde, Shawn Midlam-Mohler, Giorgio Rizzoni, Matthew Yard, Travis Trippel, Matthew Organiscak, et al. "Design of a Parallel-Series PHEV for the EcoCAR 2 Competition." SAE Technical Paper, 2012.
9. Bovee, Katherine, Amanda Hyde, Travis Trippel, Vignesh Vimalesan, Sabarish Gurusubramanian, Kishore Kumaraswamy Sai, Shawn Midlam-Mohler, and Giorgio Rizzoni. "Rapid Vehicle Architecture Selection With Use of Autonomie." In *ASME 2012 5th Annual Dynamic Systems and Control Conference Joint with the JSME 2012 11th Motion and Vibration Conference*, 119–28. American Society of Mechanical Engineers, 2012.
10. Gong, Qiuming, Shawn Midlam-Mohler, Vincenzo Marano, and Giorgio Rizzoni. "Study of PEV Charging on Residential Distribution Transformer Life." In *Smart Grid, IEEE Transactions on*, 3:404–12, 2012.
11. Gong, Q., S. Midlam-Mohler, V. Marano, and G. Rizzoni. "Distribution of PEV Charging Resources to Balance Transformer Life and Customer Satisfaction." In *Electric Vehicle Conference (IEVC), 2012 IEEE International*, 1–7. IEEE, 2012.
12. Gong, Q., S. Midlam-Mohler, E. Serra, V. Marano, and G. Rizzoni. "Distribution Transformer Tests for PEV Smart Charging Control." In *Energytech, 2012 IEEE*, 1–6. IEEE, 2012.
13. Skarke, Philipp, Shawn Midlam-Mohler, and Marcello Canova. "Waste Heat Recovery From Internal Combustion Engines: Feasibility Study on an Organic Rankine Cycle With Application to the Ohio State EcoCAR PHEV." In *ASME 2012 Internal Combustion Engine Division Fall Technical Conference*, 609–15. American Society of Mechanical Engineers, 2012.
14. Q. Gong, S. Midlam-Mohler, V. Marano, G. Rizzoni, "Optimal Control of PEV Charging Based on Residential Base Load Prediction", ASME Dynamic Systems and Control Conference (DSCC), 2011.
15. J. Meyer, S. Midlam-Mohler, S. Yurkovich, "In-cylinder Oxygen Concentration Estimation for Diesel Engines Via Transport Delay", American Control Conference, 2011.
16. K. Follen, M. Canova, S. Midlam-Mohler, Y. Guezennec, G. Rizzoni, B. Lee, G. Matthews, "A High Fidelity Lumped-Parameter Engine Model for Powertrain Control Design and Validation.", ASME Dynamic Systems and Control Conference, Cambridge, MA, United States, 2011.
17. Cooley, Robert, Davide Vezza, Shawn Midlam-Mohler, and Giorgio Rizzoni. "Model Based Engine Control Development and Hardware-in-the-Loop Testing for the EcoCAR Advanced Vehicle Competition." SAE Technical Paper, 2011.
18. Gong, Qiuming, Shawn Midlam-Mohler, Vincenzo Marano, and Giorgio Rizzoni. "An Iterative Markov Chain Approach for Generating Vehicle Driving Cycles." SAE Technical Paper, 2011.

19. Gong, Q., S. Midlam-Mohler, V. Marano, and G. Rizzoni. "PEV Charging Impact on Residential Distribution Transformer Life." In *Energytech, 2011 IEEE*, 1–6. IEEE, 2011.
20. Gong, Q., P. Tulpule, V. Marano, S. Midlam-Mohler, and G. Rizzoni. "The Role of ITS in PHEV Performance Improvement." In *American Control Conference (ACC), 2011*, 2119–24. IEEE, 2011.
21. Marano, V., P. Tulpule, Q. Gong, A. Martinez, S. Midlam-Mohler, and G. Rizzoni. "Vehicle Electrification: Implications on Generation and Distribution Network." In *Electrical Machines and Systems (ICEMS), 2011 International Conference on*, 1–6. IEEE, 2011.
22. Meyer, Jason, Shawn Midlam-Mohler, and Stephen Yurkovich. "In-Cylinder Oxygen Concentration Estimation for Diesel Engines via Transport Delay Modeling." In *American Control Conference (ACC), 2011*, 396–401. IEEE, 2011.
23. Bayar, Kerem, Beth Bezaire, Brad Cooley, John Kruckenberg, Eric Schacht, Shawn Midlam-Mohler, and Giorgio Rizzoni. "Design of an Extended-Range Electric Vehicle for the EcoCAR Challenge." In *ASME 2010 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, 687–700. American Society of Mechanical Engineers, 2010.
24. Follen, K., M. Canova, S. Midlam-Mohler, Y. Guezennec, G. Rizzoni, B. Lee, and G. Matthews. "A High Fidelity Lumped-Parameter Engine Model for Powertrain Control Design and Validation." In *ASME 2010 Dynamic Systems and Control Conference*, 695–702. American Society of Mechanical Engineers, 2010.
25. Gong, Qiuming, Shawn Midlam-Mohler, Vincenzo Marano, Giorgio Rizzoni, and Yann Guezennec. "Statistical Analysis of Phev Fleet Data." In *Vehicle Power and Propulsion Conference (VPPC), 2010 IEEE*, 1–6. IEEE, 2010.
26. Meyer, Jason, Stephen Yurkovich, and Shawn Midlam-Mohler. "Architectures for Phase Variation Compensation in AFR Control." In *American Control Conference (ACC), 2010*, 1447–52. IEEE, 2010.
27. R. Maringanti, S. Midlam-Mohler, M. Fang, F. Chiara, M. Canova, "Set-Point Generation using Kernel-Based Methods for Closed-Loop Combustion Control of a CIDI Engine," ASME DSCC2009, September, 2009.
28. J. Meyer, S. Rajagopalan, S. Midlam-Mohler, Y. Guezennec, S. Yurkovich, "Application of an Exhaust Geometry Based Delay Prediction Modal to an Internal Combustion Engine," ASME DSCC2009, September, 2009.
29. M. Fang, S. Midlam-Mohler, R. Maringanti, F. Chiara, M. Canova, "Optimal Performance of Cylinder-by-Cylinder and Fuel Bank Controllers for a CIDI Engine," ASME DSCC2009, September, 2009.
30. S. Midlam-Mohler, E. Marano, S. Ewing, D. Ortiz, G. Rizzoni, "PHEV Fleet Data Collection and Analysis," IEEE VPPC09, September 2009.
31. L. Headings, G. Washington, S. Midlam-Mohler, J. Heremans, "Thermoelectric Power Generation for Hybrid-Electric Vehicle Auxiliary Power," Proc. SPIE Int. Conference on Smart Structures and Materials, 2009, Vol. 7290, No. 13.
32. L. Headings, G. Washington, S. Midlam-Mohler, and J. Heremans, "High temperature multi-fuel combustion-powered thermoelectric auxiliary power unit", Proceedings of SMASIS2009: ASME 2009 Conference on Smart Materials, Adaptive Structures and Intelligent Systems, Oxnard, CA, USA, ASME, 123-130.
33. M. Canova, S. Midlam-Mohler, G. Rizzoni, F. Steimle, D. Boland, M. Bargende, "A Simulation Study of an E85 Engine APU for a Series Hybrid Electric Vehicle," 9th Stuttgart International Symposium on Automotive and Engine Technology, Stuttgart, Germany, 2009.
34. K. Koprubasi, A. Pezzini, B. Bezaire, R. Cooley, P. Tulpule, G. Rizzoni, Y. Guezennec, S. Midlam-Mohler, "Application of Model-Based Design Techniques for the Control Development and Optimization of a Hybrid-Electric Vehicle", SAE World Congress 2009, Detroit, MI.
35. S. Rajagopalan, S. Midlam-Mohler, S. Yurkovich, Y. Guezennec, K. Dudek, "Control Oriented Modeling of a Three Way Catalyst Coupled with Oxygen Sensors," ASME Dynamic System and Controls Conference, Ann Arbor, MI, 2008.
36. L. Headings, S. Midlam-Mohler, G. Washington, and J. P. Heremans, "High Temperature Thermoelectric Auxiliary Power Unit for Automotive Applications," ASME Conference on Smart Materials, Adaptive Structures and Intelligent Systems, 2008, Paper #610.
37. K. Sevel, M. Arnett, K. Koprubasi, C. Coburn, M. Shakiba-Heref, K. Bayar, G. Rizzoni, Y. Guezennec, S. Midlam-Mohler, "Cleaner Diesel Using Model-Based Design and Advanced Aftertreatment," SAE 2008-01-0868, 2008 International Congress, Detroit, MI, April 2008.
38. K. Dudek, B. Montello, J. Meyer, S. Midlam-Mohler, Y. Guezennec, and S. Yurkovich, "Rapid Engine Calibration for Volumetric Efficiency and Residuals by Virtual Engine Mapping," International Congress on Virtual Power Train Creation 2007, Munich, Germany, October 24-25, 2007.
39. M. Canova, S. Midlam-Mohler, Y. Guezennec, A. Soliman, and G. Rizzoni, "Control-Oriented Modeling of NOx Aftertreatment Systems," SAE ICE'07 Conference, Capri, Italy, September 2007.

40. M. Canova, F. Chiara, J. Cowgill, S. Midlam-Mohler, Y. Guezennec, G. Rizzoni, "Experimental Characterization of Mixed-Mode HCCI/DI Combustion on a Common Rail Diesel Engine," 8th International Conference on Engines for Automobile (ICE2007), Capri, Italy.
41. M. Canova, F. Chiara, M. Flory, S. Midlam-Mohler, Y. Guezennec, G. Rizzoni, "Experimental Characterization of Mixed Mode HCCI/DI Combustion on a Common Rail Diesel Engine," submitted to SAE ICE'07 Conference, Capri, Italy, September 2007.
42. M. Canova, M. Flory, Y. Guezennec, S. Midlam-Mohler, G. Rizzoni, and F. Chiara, "Dynamics and Control of DI and HCCI Combustion in a multi-cylinder Diesel engine," Paper 44, submitted to 5th IFAC Symposium on Advances in Automotive Control, Pajaro Dunes/Seascape, CA, August 2007.
43. A. Vosz, S. Midlam-Mohler, and Y. Guezennec, "Experimental Investigation of Switching Oxygen Sensor Behavior Due to Exhaust Gas Effects," Proc. of IMECE '06, Paper IMECE 2006-14915, Chicago, IL, November 2006.
44. S. Midlam-Mohler and Y. Guezennec, "A Temperature-Based Technique for Temporally and Spatially Resolved Lean NOx Trap Catalyst NOx Measurements," Proc. of IMECE '06, Paper IMECE 2006-14887, Chicago, IL, November 2006.
45. M. Canova, S. Midlam-Mohler, Y. Guezennec, G. Rizzoni, L. Garzarella, M. Ghisolfi, and F. Chiara, "Experimental Validation for Control-Oriented Modeling of Multi-Cylinder HCCI Diesel Engines," Proc. of IMECE '06, Paper IMECE 2006-14110, Chicago, IL, November 2006.
46. A. Soliman, S. Midlam-Mohler, Z. Zou, Y. Guezennec, and G. Rizzoni, "Modeling and Diagnostics of NOx Aftertreatment Systems," Proc. FISITA '06, Yokohama, Japan, October 2006.
47. Z. Zou, S. Midlam-Mohler, R. Annamalai, Y. Guezennec, V. Subramaniam, "Literature Survey of On-Board Hydrogen Generation Methods for Diesel Powertrains," Global Powertrain Conference, Novi, MI, Not Peer Reviewed, September 2006.
48. K. Follen, S. Midlam-Mohler, Y. Guezennec, "Diesel Particulate Filter Regeneration with an External Burner," Global Powertrain Conference, Novi, MI, Not Peer Reviewed, September 2006.
49. S. Midlam-Mohler and Y. Guezennec, "Regeneration Control for a Bypass-Regeneration Lean NOx Trap System," American Control Conference '06, Minneapolis, MN, Invited paper, June 2006.
50. A. Soliman, I. Choi, S. Midlam-Mohler, Y. Guezennec, G. Rizzoni, "Modeling and Diagnostics of NOx After-Treatment Systems," SAE Paper 2006-05-0208, 2006 International Congress, Detroit, MI, April 2006.
51. S. Midlam-Mohler and Y. Guezennec, "Design, Modeling and Validation of a Flame Reformer for LNT External By-Pass Regeneration," SAE Paper 2006-01-1367, 2006 SAE International Congress, Detroit, MI, April 2006.
52. S. Midlam-Mohler, and Y. Guezennec, "Modeling of a Partial Flow Diesel, Lean NOx Trap System," Proc. of IMECE '05, Paper IMECE 2005-80834, Orlando, FL, November 2005.
53. M. Canova, L. Garzarella, M. Ghisolfi, S. Midlam-Mohler, Y. Guezennec, and G. Rizzoni, "A Control-Oriented Mean-Value Model of HCCI Diesel Engines with External Mixture Formation," Proc. of IMECE '05, Paper IMECE 2005-79571, Orlando, FL, November 2005.
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57. C. Musardo, B. Staccia, S. Midlam-Mohler, Y. Guezennec, and G. Rizzoni, "Supervisory Control for NOX Reduction of an HEV with a Mixed-Mode HCCI/CIDI Engine," American Control Conference '05, Portland, OR, June 2005.
58. M. Canova, A. Vosz, D. Dumbauld, R. Garcin, S. Midlam-Mohler, Y. Guezennec, and G. Rizzoni, "Model and Experiments of Diesel Fuel HCCI Combustion with External Mixture Formation," 6th Stuttgart International Symposium on Motor Vehicles and Combustion Engines, Stuttgart, Germany, Not peer reviewed, February 2005.
59. S. Midlam-Mohler, S. Haas, Y. Guezennec, M. Bargende, G. Rizzoni, S. Haas, and H. Berner, "Mixed-Mode Diesel HCCI/DI with External Mixture Preparation," Paper F2004V258, Proc. FISITA '04 World Congress, Barcelona, Spain, May 2004.
60. Y. Guezennec, C. Musardo, B. Staccia, S. Midlam-Mohler, E. Calo, P. Pisu, and G. Rizzoni, "Supervisory Control for NOx Reduction of an HEV with a Mixed-Mode HCCI/DI Engine," Paper F2004F233, Proc. FISITA '04 World Congress, Barcelona, Spain, May 2004.

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62. Y. Guezennec, S. Midlam-Mohler, M. Tateno, and M, Hopka, "A 2-Stage Approach to Diesel Emission Management in Diesel Hybrid Electric Vehicles," Proc. 2002 IFAC Meeting, Barcelona, Spain, July 2002.
63. M. Hopka, A. Brahma, Q. Ma, S. Midlam-Mohler, G. Paganelli, Y. Guezennec, and G. Rizzoni, "Design, Development and Performance of Buckeyebrid: The Ohio State Hybrid Electric FutureTruck 2001," SAE SP-1701, Not peer reviewed, March 2002.

Susan Nelson

Greenville, South Carolina

Project Management and Technical Consulting Services
Focus: Transportation Technology and Energy Efficiency

Career Highlights

- Management of projects in technical, research, and policy investigations, comprised of interdisciplinary and inter-organizational participants from corporate, national laboratory, university and regulatory areas.
- Facilitation of team and stakeholder groups to clarify and obtain consensus on business needs, project scope and objectives, solution development and ranking, and management of risks.
- Over 14 years of research and development experience for heavy trucks, including direct product development and validation in the North American, European, and Japanese markets, with additional light duty component development for global market approvals.
- Direct experience in heavy truck fleets to optimize selection and use of fuel-efficient technologies and evaluation methods. Planning and participation in joint testing at fleet test sites.

Current Position – Owner and Managing Member - Blue Stripe Scientific, LLC – Greenville, SC

- Acquired ownership and management of Blue Stripe Scientific, LLC in 2012. Updated the business focus to include project management in addition to technical consulting in research and development.
- Project Manager and technical service provider to assess approaches to monitor and maintain inflation pressure in heavy duty vehicle tires, under contract to the North American Council for Freight Efficiency (NACFE). Defined categories of technologies to permit characterization of diverse product offerings according to common features and functionalities. Conducted and analyzed stakeholder input data through face-to-face and telephone interviews, and through Internet surveys developed specifically for the project. Project deliverables include a final report, a technology payback calculator, and a matrix summary of the various tire pressure technologies together with their primary functional characteristics, advantages, and limitations. Results are publicly available at nacfe.org/projects.

Relevant Prior Professional Experience

Michelin North America – Michelin America's Research Company, Greenville, South Carolina

Senior Principal Project Manager, 2009-2011 – Heavy Truck Tire Product Line

- Led two cross-functional research teams (32 members) in high-profile, multi-phase projects for development of six new long haul, heavy truck tire lines, including next generation fuel-efficient products, for delivery to the corporate business team. Set strategic technical direction of the projects, and managed the planning, scheduling, budget, and stakeholder requirements – including liaison with marketing and sales, research and operational technical directors, corporate level quality, functional managers, and global level portfolio managers. Responsible for project level reporting and analysis of performance indicators, including synthesis of team reports and presentations.
- Project lead for Michelin's participation in the Navistar-led DOE SuperTruck project. Activated a sub-team of 4 of the 9 participating organizations for collaborative redesign of truck axle and wheel-end components. Enabled and participated in inter-company track testing using SAE Type II fuel economy test methods.

Senior Project Leader, 2008-2009

- Project and technical lead for two exploratory projects in heavy truck tire fuel efficiency and long-term endurance performance using emerging materials and design technologies.
- Michelin technical liaison to EPA SmartWay program.
- Directed Michelin participation in research study of heavy truck rollover sensitivity with university and national laboratory partners in conjunction with the National Transportation Research Center, Inc. Publication of evaluations/recommendations for a Class 8 tractor in combination with flatbed, box, and tanker trailers.

Susan Nelson – Page 2

Manager -Truck Tire Innovation and Endurance Research Team, 2006-2008

- Managed team of project engineers, finite element simulation analysts, and manufacturing engineers for product innovation, test and test systems development, and fleet placement and tracking of long-term tire performance from clean-sheet conception through physical prototype stage.
- Responsible for streamlining cycles of prototype development and testing.
- Provided industry advice and support to Oak Ridge National Laboratory multi-year field operational test of impact of tire rolling resistance on heavy truck fuel consumption.

Supplemental Work Experience

Michelin North America and Michelin France 1985-2006. Engineer in both OE passenger car and heavy truck tire development, vehicle vibration analysis, and quality and manufacturing processes. Development engineer for heavy duty tire products in the North American, European, and Japanese markets. Development engineer for light duty products destined for global markets, subject to OEM and internal Michelin performance specifications, and country specific regulatory requirements.

Tennessee Valley Authority 1979-1985, Norris, Tennessee. Water Resources/Civil Engineer responsible for TVA river flow and power plant effluent computer simulations and field validation, including response planning for potential emergency incidents at nuclear facilities.

Education – Massachusetts Institute of Technology, Cambridge, Massachusetts

1977 Bachelor of Science, Civil Engineering
1979 Master of Science, Civil Engineering – Master's thesis program in fluid dynamics and environmental engineering

Certifications and Professional Affiliations

Professional Engineer (PE), 1982 – Present
Certified Quality Engineer (CQE), 1989 – Present
Project Management Professional (PMP), 2012 - Present
American Trucking Associations Technology & Maintenance Council
Society of Automotive Engineers
American Society for Quality Senior Member
Sigma Xi, Scientific Research Society

Publications and Joint Research

E. Johnson, S. Nelson, F. Marlier, S. Nicolas, and M. Rolland, "Optimized Drive Axle Design for Class 8 Tractors Equipped with New Generation Wide Base Single Tires" SAE Technical Paper 2009-01-2861, October 6, 2009.

D. Pape, M. Arant, S. Nelson, O. Franzese, H. Knee, T. LaClair, U. Attanayake, R. Hathaway, M. Keil, and K. Ro,"Heavy Truck Rollover Characterization (Phase B) Final Report", Study funded by the National Transportation Research Center under a grant from the U.S. Department of Transportation Research and Innovative Technology Administration (#DTRT06G-0043), September 2009.

M. Arant, D. Hall, S. Nelson, R. Hathaway, M. Keil, P. Pollock, O. Franzese, H. Knee, N. Wood, D. Pape, J. Petrolino, S. Yeakel, "Heavy Truck Rollover Characterization (Phase A) Final Report" (NTRCI-50-2008-006), Study funded by the National Transportation Research Center under a grant from the U.S. Department of Transportation Research and Innovative Technology Administration (#DTRT06G-0043), September 2008.

G.J. Capps, O. Franzese, H.E. Knee, M.B. Lascurain and P. Otaduy,"Class-8 Heavy Truck Duty Cycle Project Final Report" ORNL/TM-2008/122, Oak Ridge National Laboratory, Oak Ridge, TN (2008).

Presentations

"Truck Tires and Rolling Resistance", presented February 2009 as representative of Michelin Americas Research Company to the National Academy of Sciences Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles. Presentation materials including range of common tire rolling resistance levels as well as simulation results of the effect of tire rolling resistance on fuel economy over various drive cycles were included in the Committee's March 2010 report, "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles", ISBN: 978-0-309-14982-2.

"Wide Thing: A Case Study of Innovating in a Mature Market", Susan Nelson, Michelin Americas Research Company, Front End of Innovation (FEI) Conference, Boston, MA, May 20-21, 2008.

"Improving Test Practices for Fuel Economy Evaluations of Heavy Trucks", Susan Nelson, Michelin Americas Research Company, presented at the 23rd Annual Clemson University Tire Industry Conference, March 14-16, 2007, Hilton Head, SC.

JOHN P. NUSZKOWSKI, Ph.D.
University of North Florida (UNF)
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Building 50, Room 3128
Jacksonville, FL 32224
Phone: (904) 620-1683
john.nuszkowski@unf.edu

EDUCATION

West Virginia University, Morgantown, WV
Major: Mechanical Engineering
Degree: Doctorate of Philosophy, August 2008
Dissertation Chair: Gregory J. Thompson, Ph.D.
Dissertation: The Effects of Fuel Additives on Diesel Engine Emissions during Steady State and Transient Operation

West Virginia University, Morgantown, WV
Major: Mechanical Engineering
Degree: Master of Science, August 2005
Thesis Chair: Gregory J. Thompson, Ph.D.
Thesis: Staten Island Ferry Emissions Reduction

Rochester Institute of Technology, Rochester, NY
Major: Mechanical Engineering
Degree: Bachelor of Science, May 2003

EMPLOYMENT HISTORY

University of North Florida, Mechanical Engineering Program, Jacksonville, FL
Assistant Professor 8/2011 – present
Teach mechanical engineering courses, acquire project funding, and write proposals, publications and conference papers on research topics.

West Virginia University, Department of Mechanical and Aerospace Engineering, Morgantown, WV
Research Adjunct Professor 08/2011 – present
Research heavy-duty vehicle and engine performance and emissions.

West Virginia University, Department of Mechanical and Aerospace Engineering, Morgantown, WV
Research Assistant Professor 12/2008 – 7/2011

Research heavy-duty vehicle and engine performance and emissions. Acquire project funding and write proposals, publications and conference papers on research topics.

West Virginia University, Department of Mechanical and Aerospace Engineering, Morgantown, WV

Project Coordinator 08/2008 – 10/2008

Research diesel engine emissions, write reports and papers on research topics.

West Virginia University, Department of Mechanical and Aerospace Engineering, Morgantown, WV

Graduate Research Assistant 08/2003 – 07/2008

Research diesel engine emissions, write reports, and papers on research topics. Provide support to research programs.

General Electric - Power Systems, Schenectady, NY

Controls Engineer, Intern 09/2002 – 11/2002

Research problems, research new ideas, write reports, and update gas turbine controls code and documentation.

General Electric - Power Systems, Schenectady, NY

Mechanical Engineer, Intern 03/2002 – 05/2002

Design and research of steam turbine parts in the new product introduction department.

Laerdal Medical Corporation, Wappingers Falls, NY

Mechanical Design Engineer, Intern 09/2001 – 11/2001

Conceived innovative products for emergency medicine. Testing and shop experience.

Gleason Works, Rochester, NY

CAD Applications Engineer, Intern 03/2001 – 05/2001

Modeled parts and assemblies using Pro-Engineer. Create tutorials and one-on-one help based on Pro-Engineer.

General Electric - CRD, Schenectady, NY

Mechanical Engineer, Intern 06/2000 – 11/2000

Responsible for laboratory facility, testing, data acquisition, and preliminary theories based on data.

ENGINEERING INSTITUTION MEMBERSHIPS

American Society Of Mechanical Engineers (ASME), Journal and Conference Paper Reviewer

Society of Automotic Engineers (SAE), Journal and Conference Paper Reviewer

INSTRUCTION

Fall Semester, 2014, UNF, Thermodynamics I, EML 3100, Enrollment 75.

Fall Semester, 2014, UNF, Introduction to Engineering II, ENG 2009, Enrollment 47.

Spring Semester, 2014, UNF, Thermodynamics II, EML 3101, Enrollment 74.

Spring Semester, 2014, UNF, Internal Combustion Engines, EML 4930, Enrollment 15.

Spring Semester, 2014, UNF, Internal Combustion Engines, EML 6933, Enrollment 4.

Spring Semester, 2014, UNF, Introduction to Engineering II, ENG 2009, Enrollment 35.

Fall Semester, 2013, UNF, Machine Design, EML 4501, Enrollment 50.

Fall Semester, 2013, UNF, Thermodynamics I, EML 3100, Enrollment 64.

Fall Semester, 2013, UNF, Introduction to Engineering II, ENG 2009, Enrollment 47.

Summer Semester, 2013, UNF, Thermodynamics I, EML 3100, Enrollment 48.

Spring Semester, 2013, UNF, Thermodynamics II, EML 3101, Enrollment 57.

Spring Semester, 2013, UNF, Internal Combustion Engines, EML 4930, Enrollment 18.

Spring Semester, 2013, UNF, Internal Combustion Engines, EML 6933, Enrollment 2.

Fall Semester, 2012, UNF, Introduction to Engineering II, ENG 2009, Enrollment 42.

Fall Semester, 2012, UNF, Machine Design, EML 4501, Enrollment 38.

Fall Semester, 2012, UNF, Thermodynamics I, EML 3100, Enrollment 39.

Summer Semester, 2012, UNF, Applied Vehicle Powertrain, EML 4930, Enrollment 15.

Summer Semester, 2012, UNF, Sustainable Engineering Design, CGN 4931, Enrollment 8.

Spring Semester, 2012, UNF, Energy Systems Lab, EML 4004L, Section 1, Enrollment 26.

Spring Semester, 2012, UNF, Energy Systems Lab, EML 4004L, Section 2, Enrollment 26.

Spring Semester, 2012, UNF, Thermodynamics II, EML 3101, Enrollment 37.

Fall Semester, 2011, UNF, Introduction to Engineering II, ENG 2009, Enrollment 75.

Fall Semester, 2011, UNF, Machine Design, EML 4501, Enrollment 60.

Fall Semester, 2011, UNF, Thermodynamics I, EML 3100, Enrollment 41.

Spring Semester, 2011, WVU, Thermodynamics, MAE 320, Enrollment 50.

Fall Semester, 2010, WVU, Thermodynamics, MAE 320, Enrollment 39.

Fall Semester, 2010, WVU, Machine Design and Manufacturing, MAE 454, Enrollment 22.

Fall Semester, 2007, WVU, Machine Design and Manufacturing, MAE 454, Enrollment 27.

GUEST LECTURES

“An Experimental Investigation of the Thermal Efficiency, Combustion Process, and Emissions of a Heavy-Duty Diesel Engine Enriched with Hydrogen (H_2),” UNF ASME Chapter, February 12, 2013.

“Engine and Powertrain Research,” UNF ASME Chapter, January 18, 2013.

“Locomotive Emissions Measurement,” Fall Semester, 2010, WVU, Heavy Duty Vehicle Emissions, MAE 525 (Graduate Course), Enrollment 19.

“Chemical Kinetics,” Spring Semester, 2010, WVU, Advanced

Thermodynamics 2, MAE 621 (Graduate Course), Enrollment 13.

“In-cylinder Convection Heat Transfer,” Spring Semester, 2010, WVU, Advanced Internal Combustion Engines, MAE 593Q (Graduate Course), Enrollment 27.

“In-cylinder Pressure Measurement,” Fall Semester, 2009, WVU, Engine Combustion and Emissions, MAE 493H, Enrollment 8.

“The Torque Required for Power Screws,” Fall Semester, 2008, WVU, Machine Design and Manufacturing, MAE 454, Enrollment 97.

“Staten Island Ferry Emissions Reduction,” Spring Semester, 2007, WVU, Conventional and Hybrid Vehicle Emissions, MAE 593H (Graduate Course), Enrollment 12.

GRADUATE STUDENT THESIS ADVISOR

Merritt, Brock MSME (08/11)
“Juxtaposition of In-Use Vehicular Emissions Measurement Equipment”

Morris, Melissa Ph.D. (08/11)
“Development of an Artificial Neural Network to Predict In-Use Engine Emissions”

Kimble, Nathan MSME (08/11)
“Model Based Evaluation of the Differences between Full and Partial Flow Particulate Matter Sampling Systems”

GRADUATE STUDENT THESIS COMMITTEES

Ryskamp, Ross Ph.D. (05/14)
“Investigation of High Reactivity Fuel Property Effects on Reactivity Controlled Compression Ignition Combustion”

Olatunji, Idowu MSME (12/10)
“Emissions Characterization and Particle Size Distribution from a DPF-Equipped Diesel Truck Fueled with Biodiesel Blends”

Ryskamp, Ross MSME (12/10)
“Exploration of Injection Strategy and Fuel Property Effects on Advanced Combustion”

Ice, Jason MSME (12/10)
“Investigation of EGR and Fuel Property Effects on Advanced Combustion

Strategies Using In-cylinder Combustion Analyses"

Balakrishnan, Ramamoorthy MSME (08/11)
"Investigation of Particulate Matter Size Distribution and Concentration during Low Temperature Combustion"

PEER REVIEWED PUBLICATIONS

Nuszkowski, J., Chvala, J., McCollum, M., and Kinnaly, E., "The Influence of Ambient Wind Conditions on Aerodynamic Friction Energy during On-road Vehicle Operation," Proceedings of the Institution of Mechanical Engineers, Part

D: Journal of Automobile Engineering, (Submitted February 2013).

Li, H., Liu, S., Gatts, T., Liew, C., Wayne, S., **Nuszkowski, J.**, Thompson, G., and Clark, N., "An Investigation of NO_2 Emissions from a Heavy-Duty Diesel Engine Fumigated with H_2 and Natural Gas," Journal of Combustion Science and Technology, Vol. 184, No. 12, pp. 2008-2035, 2012.

Carder, D., Ryskamp, R., **Nuszkowski, J.**, Li, H., Clark, N., Thompson, G., Gautam, M., and Wayne, S., "Fuels to Enable Light-Duty Diesel Advanced Combustion Regimes," Coordinating Research Council, Inc., August, 2012.

Nuszkowski, J., Flaim, K., and Thompson, G., "The Effect of Cetane Improvers and Biodiesel on Diesel Particulate Matter Size," SAE International Journal of Fuels and Lubricants, Vol. 4, No. 1, pp. 23-33, 2011.

Liew, C., Li, H., **Nuszkowski, J.**, Liu, S., Gatts, T., Atkinson, R., and Clark, N., "An Experimental Investigation of the Combustion Process
of a Heavy-Duty Diesel Engine Enriched with H_2," International Journal of Hydrogen Energy, Vol. 35, No. 20, pp. 357-365, 2010.

Thompson, G. and **Nuszkowski, J.**, "Neat Fuel Influence on Biodiesel Blend Emissions," International Journal of Engine Research, Vol. 11, No. 1, pp. 61-77, 2010.

Nuszkowski, J., Tincher, R., and Thompson, G., "Evaluation of the NOx Emissions from Heavy Duty Diesel Engines with the Addition of Cetane Improvers," Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, Vol. 223, No. 8, pp. 1049-1060, 2009.

Nuszkowski, J., Thompson, G., and Ursic, M., "The Influence of Accelerator Pedal Position Control during Transient Laboratory Testing on Heavy Duty Diesel Engines," SAE International Journal of Engines, Vol. 2, No. 1, pp. 398-404, 2009.

Nuszkowski, J., Clark, N., Spencer, T., Carder, D., Gautam, M., Balon, T., and Moynihan, P., "Atmospheric Emissions from a Passenger Ferry with Selective Catalytic Reduction," Journal of the Air & Waste Management Association, Vol. 59, No. 1, pp. 18-30, 2009.

Nuszkowski, J., Spencer, T., Clark, N., and Balon, T., "On-board Emissions Measurement and Characterisation of Marine Diesel Engines," Journal of Marine Design and Operations Proceedings of IMarEST - Part B, No. 11, pp. 15-26, 2007.

PEER REVIEWED CONFERENCE PAPERS/PRESENTATIONS

Bonsack, P., Ryskamp, R., Besch, M., Carder, D., Gautam, M., and **Nuszkowski, J.**, "Number Concentration and Size Distributions of Nanoparticle Emissions during Low Temperature Combustion using Fuels for Advanced Combustion engines (FACE)," Warrendale, PA, SAE Technical Paper No. 2014-04-01, 2014.

Bonar, H. and **Nuszkowski, J.**, "Gaining "Lost Work" for a Greener Planet," 5th International Conference, Ammonia Refrigeration Technology (Ohrid, Republic of Macedonia), May 9-11, 2013.

Littera, D., Bonsack, P., Ryskamp, R., Besch, M., Carder, D., **Nuszkowski, J.**, and Gautam, M., "Concentration and Size Distributions of Nanoparticle Emissions during Low Temperature Combustion using Fuels for Advanced Combustion Engines," 16th ETH Conference on Combustion Generated Nanoparticles (Zurich, Switzerland), June 24-27, 2012.

Ryskamp, R., **Nuszkowski, J.**, Carder, D., Bonsack, P., and Gautam, M., "Comprehensive Investigation of Fuel Property Effects on Light-Duty Compression Ignition Advanced Combustion" 22nd CRC On-Road Vehicle Emissions Workshop (San Diego, California), 2012.

Nuszkowski, J., Flaim, K., and Thompson, G., "The Effect of Cetane Improvers and Biodiesel on Diesel Particulate Matter Size," Warrendale, PA, SAE Technical Paper No. 2011-01-0330, 2011.

Dam, M., **Nuszkowski, J.**, and Thompson, G., "Experimental Investigation into the Effects of Oil Aging on Laboratory Measurement of Emissions from a Heavy-duty Diesel Engine," Warrendale, PA, SAE Technical Paper No. 2011-01-1163, 2011.

Clark, N., McKain, D., Sindler, P., Jarrett, R., **Nuszkowski, J.**, Gautam, M., Wayne, S., Thompson, G., and Sonny, R., "Comparative Emissions from Diesel and Biodiesel Fueled Buses from 2002 to 2008 Model Years," Warrendale, PA, SAE Technical Paper No. 2010-01-1967, 2010.

Olatunji, I., Clark, N., Sindler, P., McKain, D., Thompson, G., Gautam, M., Wayne, S., and **Nuszkowski, J.**, "Biodiesel Blend Emissions of a 2007 Medium Heavy Duty Diesel Truck," Warrendale, PA, SAE Technical Paper No. 2010-01-1968, 2010.

Nuszkowski, J. and Thompson, G., "Biodiesel Blend NOx Emissions from Heavy Duty Diesel Engines," 2nd International Congress on Biodiesel: The Science and The Technologies, Munich, Germany, November, 2009.

Nuszkowski, J. and Thompson, G., "The Influence of Accelerator Pedal Position Control during Transient Laboratory Testing on Heavy Duty Diesel Engines," Warrendale, PA, SAE Technical Paper No. 2009-01-0619, 2009.

Nuszkowski, J. and Thompson, G., "Application and Repeatability of Transient Heat Release Analysis for Heavy Duty Diesel Engines," Warrendale, PA, SAE Technical Paper No. 2009-01-1125, 2009.

Nuszkowski, J., Thompson, G., Tincher, R., and Clark, N., "Heat Release and Emission Characteristics of B20 Biodiesel Fuels During Steady State and Transient Operation," Warrendale, PA, SAE Technical Paper No. 2008-01-1377, 2008.

Nuszkowski, J., Bolyard, J., Thompson, G., and Carder, D., "In-Use Heavy-Duty Diesel Emissions Measurement Using An Air-to-Fuel Ratio Derived Exhaust Flow Rate," Proceedings of ICEF2007 ASME Internal Combustion Engine Division 2007 Fall Technical Conference, ASME Paper No. ICEF2007-1780, Charleston, SC, 2007.

Nuszkowski, J., Thompson, G., and Clark, N., "Experimental and Error Analysis Investigation into Dilution Factor Equations," Warrendale, PA, SAE Technical Paper No. 2007-01-0310, 2007.

Nuszkowski, J., Thompson, G., Chiaramonte, M., Hu, J., and Moles, N., "Pressure Drop and Cleaning of In-Use Ash Loaded Diesel Particulate Filters," Warrendale, PA, SAE Technical Paper No. 2006-01-3256, 2006. (Included in the book, Johnson, T.V., "Diesel Particulate Filter Technology", SAE, Toronto, CA, 2007).

CONFERENCE POSTERS

Nuszkowski, J., Olatunji, I., Clark, N., Werner, T., and McLaughlin, S., "Predicting and Utilizing the Vehicle's Past and Future Road Grade," Directions in Engine-Efficiency and Emissions Research Conference (Detroit, Michigan), October 2011.

Ice, J., Ryskamp, R., Balakrishnan, R., **Nuszkowski, J.**, and Shade, B., "In-cylinder Combustion Techniques to Identify Advanced Combustion," 21st CRC On-Road Vehicle Emissions Workshop (San Diego, California), 2011.

Ryskamp, R., Ice, J., Balakrishnan, R., **Nuszkowski, J.**, and Shade, B., "Characterization of Fuels to Enable Advanced Combustion in a Light Duty Compression Ignition Engine Through Emissions and Performance Measurements," 21st CRC On-Road Vehicle Emissions Workshop (San Diego, California), 2011.

Shade, B., **Nuszkowski, J.**, Thompson, G., Wayne, S., Gautam, M., and Clark, N., "Regulated Emissions of Heavy-Duty Diesel Engines - Past, Present and Future," Proceedings of the Better Air Quality (BAQ) 2010, Singapore, November 2010.

Nuszkowski, J., Shade, B., "The Impact of using Derived Fuel Consumption Maps to Predict Fuel Consumption," Directions in Engine-Efficiency and Emissions Research Conference (Detroit, Michigan), September 2010.

Shade, B., **Nuszkowski, J.**, Thompson, G., Wayne, S., Gautam, M., Clark, N., and, Atkinson, C., "Regulated Emissions of Heavy-Duty Diesel Engines - Past, Present and Future," 20th CRC On-Road Vehicle Emissions Workshop (San Diego, California), 2010.

Carder, D., **Nuszkowski, J.**, Shade, B., Thompson, G., Clark, N., and Gautam, M., "Development and Demonstration of a Next Generation Mobile Heavy-Duty Emissions Testing Laboratory," 20th CRC On-Road Vehicle Emissions Workshop (San Diego, California), 2010.

Carder, D., Wu, Y., **Nuszkowski, J.**, Shade, B., Clark, N., and Gautam, M., "Development of a Transportable, 1065-Compliant Emissions Measurement System," Directions in Engine-Efficiency and Emissions Research Conference (Dearborn, Michigan), 2009.

Shade, B., **Nuszkowski, J.**, Thompson, G., and Clark, N., "Statistical Analysis of Transient Cycle Test Results in a 40 CFR Part 1065 Engine Dynamometer Test Cell," Directions in Engine-Efficiency and Emissions Research Conference (Dearborn, Michigan), 2009.

Liew, C.M., Li, H., Gatts, T., **Nuszkowski, J.**, Xu, S., Rapp, B., and Clark, N., "An Investigation of Combustion and Emissions Characteristics of Heavy-Duty Diesel Engines Supplemented with Hydrogen," Directions in Engine-Efficiency and Emissions Research Conference (Dearborn, Michigan), 2009.

PROJECTS

“Design and Construction of a Fluid Amplifier Cooler,” Bonar Engineering, Inc., Jacksonville, FL, June 2014 – June 2015, $25,000.

“Energy Efficient Vehicles,” UNF Foundation Board, Jacksonville, FL, January 2014 – December 2014, $15,000.

“Small Scale Engine Performance Screening for Alternative Navy Fuels,” Principle Investigator, West Viriginia University, Morgantown, WV, January 2013 – December 2013, $6,000.

“Assessment of “the Expander,” an Apparatus and Method for converting Thermal to Electrical Energy,” Henry B. Bonar II, Jacksonville, FL, November 2011 – August 2012, $10,176.

“Support for the Fuels to Enable Light-Duty Diesel Advanced Combustion Regimes Project,” Principle Investigator , West Viriginia University,

Morgantown, WV, August 2011 – March 2012, $22,000.

“Fuels to Enable Light-Duty Diesel Advanced Combustion Regimes,” Principle Investigator as of 12/30/2010, Coordinating Research Council, Inc., Dec. 1, 2008 – Nov. 30, 2011, Alpharetta, GA, $434,514.

“Norfolk Southern Tier 0 Emissions Evaluation,” Co-Investigator, Norfolk Southern Railway Company, Nov. 1, 2010 – July. 31, 2010, Roanoke, VA, $166,452.

“Regulated Gaseous and PM Emissions of In-use Heavy-Duty Trucks,” Principle Investigator as of 12/29/2010, Caterpillar, Inc., Oct. 1, 2009 – Jun. 30, 2011, Mossville, IL, $159,626.
“Norfolk Southern Tier 0 Emissions Evaluation,” Co-Investigator, Norfolk Southern Railway Company, Aug. 1, 2010 – Dec. 31, 2010, Roanoke, VA, $131,798.

“Norfolk Southern Tier 0 Emissions Evaluation,” Co-Investigator, Norfolk Southern Railway Company, Mar. 1, 2010 – Dec. 31, 2010, Roanoke, VA, $166,452.

“CARB Verification of Süd-Chemie / Diesel Emission Technologies PDPF,” Co-Investigator, Süd-Chemie, Inc., June 1, 2009 – Dec. 31, 2010, Needham, MA, $83,460.

"TCEQ Certification of a Fuel Additive," Co-Investigator, Afton Chemical Corporation, Dec. 1, 2009 – Dec. 31, 2010, Richmond, VA, $98,823.

"Rypos Level 3 Plus TRU Verification Using the CARB Procedure," Principle Investigator as of 12/29/2010, Rypos, Inc., Jun. 30, 2011 – Dec. 31, 2010, Holliston, MA, $68,909.

"Norfolk Southern Tier 0 Emissions Evaluation," Co-Investigator, Norfolk Southern Railway Company, Aug. 1, 2009 – Dec. 31, 2010, Roanoke, VA, $92,747.

"Regulated Gaseous and PM Emissions of In-use Heavy-Duty Trucks," Principle Investigator as of 12/29/2010, Caterpillar, Inc., Dec. 1, 2009 – Jun. 30, 2011, Mossville, IL, $300,000.

"Biodiesel Fleet Emissions and Greenhouse Gas Demonstration," Co-Investigator, Central Florida Regional Transportation Authority (LYNX), Oct. 1, 2009 – Mar. 31, 2010, Orlando, FL, $488,513.

"Engine Dynamometer Researh for an Air Moving Device," Co-Investigator, Global Sus. Technologies, Oct. 1, 2009 – Dec. 31, 2009, Knoxville, TN, $46,889.

"Refined Fuel Additive Effects on Emissions," Principle Investigator, Afton Chemical Corporation, Sep. 1, 2009 - June 30, 2010, Richmond, VA, $16,466.

"Verification of 40 CFR Part 92 Compliance Testing for Auxiliary Engines," Principle Investigator, Emisstar, Aug. 1, 2009 – Dec. 31, 2009, New Boston, NH, $9,282.

"Norfolk Southern Tier 0 Emissions Evaluation," Co-Investigator, Norfolk Southern Railway Company, Aug. 1, 2009 – Dec. 31, 2009, Roanoke, VA, $156,722.

"Evaluation of Production Heavy-Duty Diesel Engines for 2010 Emissions Compliance," Co-Investigator, Mack Trucks, Inc., July 1, 2009 – Dec. 31, 2009, Hagerstown, MD, $88,190.

"Fuel Additive Effects on Emissions," Co-Investigator, Afton Chemical Corporation, May 1, 2009 – Apr. 30, 2010, Richmond, VA, $16,400.

"Advanced Powertrain Simulation," Principle Investigator, Mack Trucks, May 1, 2009 – Jan. 31, 2010, Hagerstown, MD, $50,641.

DEPARTMENT, COLLEGE, UNIVERSITY SERVICE

1. SoE Guidelines Committee, Department Service, UNF, Spring 2014.
2. Graduate Program Review Committee, Department Service, UNF, Fall 2013 - Spring 2014.
3. ME Search Committee, Department Service, UNF, Fall 2013 - Spring 2014.
4. Engineering Scholarship Committee, Department Service, UNF, Fall 2013 - Spring 2014.
5. Design Report Committee, Department Service, UNF, Spring 2013.
6. Outstanding Undergraduate Teaching Award Committee (Chair), College Service, UNF, Spring 2013.
7. Outstanding Graduate Teaching Award Committee, College Service, UNF, Spring 2013.
8. Critical Thinking Committee Member, Department Service, UNF, Fall 2011 – Spring 2013.
9. Outstanding Undergraduate Teaching Award Committee, College Service, UNF, Spring 2012.
10. Critical Thinking Committee Member, Department Service, UNF, Fall 2011 – Spring 2012.
11. Faculty Retention Committee Member, University Service, WVU, Spring – Fall 2010.

SYNERGISTIC ACTIVITIES

- Evaluation and development of novel thermodynamic systems
- Evaluating fuels for advanced combustion

- Investigating complete powertrain strategies that decrease fuel consumption.
- Development and evaluation of a new raw emissions laboratory for testing locomotives and marine vessels.
- Evaluation of a new chassis emissions laboratory for testing vehicles year 2007 or newer.
- Evaluation of biodiesel fuels and diesel fuel additives using in-cylinder pressure measurement during steady state and transient testing.
- Development of combustion models based on the measurement of in-cylinder pressure for diesel engines under steady state and transient operation.
- Measurement of gaseous and particulate emissions from heavy-duty on-road and off-road vehicles and equipment for atmospheric pollutant inventory modeling and prediction.
- Development and evaluation of advanced exhaust aftertreatment systems such as catalyzed particulate filters, selective catalytic reduction (SCR), and oxidation catalyst systems for diesel engines.

APPENDIX B

CHARGE TO REVIEWERS

Peer Review Charge

DTNH22-13-D-00298, Task Order 0003: Report 3

“Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #3”

Background and Context for this Review

In 2010, President Obama directed the U.S. Environmental Protection Agency (EPA) and the Department of Transportation’s National Highway Traffic Safety Administration (NHTSA) to develop joint greenhouse gas and fuel efficiency standards for heavy-duty trucks. The agencies met that directive in August 2011 by finalizing first-of-a-kind standards for new heavy-duty vehicles in model years 2014 through 2018.

In early 2014, President Obama directed NHTSA and EPA to develop and issue the next phase ("Phase 2") of medium- and heavy-duty (MD/HD) vehicle fuel efficiency and greenhouse gas (GHG) standards, which will build on the Phase 1 standards. Since then, NHTSA and EPA have been working to develop the Phase 2 standards using a wide variety of inputs, including research reports, National Academy of Sciences (NAS) studies, industry literature, manufacturer-supplied data, simulation work, and other sources to inform regulatory development. The report to be reviewed under this peer review, Southwest Research Institute (SwRI) Report #3, is one such input.

External, objective peer review is employed by NHTSA and other federal agencies to strengthen key research documents and ensure that the quality of the final published information meets the standards of the scientific and technical community. External peer review supports sound decision-making by helping to ensure the conceptual soundness the approaches; adequate, appropriate, and competent development of technical research, analyses and models; the quality of the inputs, processing, and output of computer models (when part of the analysis); the validity of the results/conclusions based on the assumptions, analysis, and available data; and proper documentation of the work.

After receiving peer reviewer comments on SwRI Report #3, NHTSA will respond as appropriate in the agency’s judgment, resulting in various changes to improve the review document before it is final. NHTSA will draw from the final SwRI report, along with information, data, and inputs from many other sources, during the subsequent stages of the regulatory process, which include issuing a Notice of Proposed Rulemaking (NPRM) and the draft Regulatory Impact Analysis (RIA). The Phase 2 NPRM and draft RIA will go through the standard federal open rulemaking process, which includes a public review and comment period, before NHTSA issues a Final Rule (FR) and Final Regulatory Impact Analysis (FRIA).

Southwest Research Institute (SwRI) Report Series

In September 2012, NHTSA competitively awarded a contract to Southwest Research Institute to conduct research in support of the Phase 2 federal fuel efficiency (FE) and GHG standards. Tasks included determining the baseline fuel efficiency and emissions levels and technologies of current model year commercial medium- and heavy-duty on-highway vehicles and work trucks, as well as projections of Phase 2 (post-2018 model year) fuel efficiency and emission reduction technologies. The scope encompassed technologies for chassis and final-stage manufacturer vehicles and trailers, maintenance cost, material application, future design, electric and hybrid propulsion systems, capital investment, retail cost, and any other applicable advanced technologies. Estimates of the costs, fuel savings effectiveness, availability, and applicability of technologies were done for each individual vehicle class category (e.g., segment).

The resulting report series consists of three sequential reports. All three reports are from the same project, and involve the same technologies, engines, and vehicles; however, due to their large size, they have been separated into three documents to facilitate review and publication.

Report #1 in the series provides results of simulation studies for the individual engine and vehicle FE/GHG-improving technologies over a range of drive cycles and payloads. Report #2 contains an estimate the costs of implementation of each individual technology in the areas of incremental retail prices, life cycle costs, and indirect economic effects. This peer review covers the Report #3, which provides results from simulation of packages of the FE/GHG-improving technologies studied in the first two reports. These results include:

- Results from simulation of both engine and vehicle technology packages.
- The results of parameter sweep studies, covering aerodynamic drag, tire rolling resistance, vehicle empty weight, and axle ratios.
- A brief review of vocational truck specification issues and impacts of fuel efficiency.
- A survey of natural gas vehicle costs, along with some implementation issues for natural gas-powered vehicles.

SwRI Report #3 Overview

SwRI report # 3 is divided into six sections:

- **Section 1** provides an overview of the project and introduction to the research described in all three project reports.
- **Section 2** covers the results of a task in which SwRI created packages of engine and vehicle technologies by combining individual technologies described in Report #1. These combinations were meant to explore questions regarding which technologies provide benefits that are additive, which provide benefits that are not additive, and whether any technologies are synergistic. In addition, the bottoming cycle model developed and reported in Report #1 was extended to include a wider range of working fluids and the option of a recuperator. The recuperator is a device that has the effect of increasing bottoming cycle power output and reducing heat rejection, both at the expense of additional cost, weight, and system complexity. The technology analysis for Class 2b is expanded by simulations of various hybrid configurations. This work was performed by Argonne National Laboratories.
- **Section 3** covers the results of a task in which SwRI performed sweeps of vehicle parameters to determine their effect on vehicle fuel consumption. These sweeps included changes to the aerodynamic drag coefficient (Cd), the tire rolling resistance (Crr), the vehicle empty weight, and the axle ratio. Vehicle performance and fuel consumption were evaluated over a range of driving cycles.
- **In Section 4**, results presented in Sections 2 – 4 are used to evaluate how vehicle specification can affect performance and fuel consumption of vocational trucks. The fuel economy of these trucks has been given much less attention by researchers than tractor-trailer trucks, so there is a need to evaluate vocational trucks in more detail.
- **Section 5** describes a survey of current truck market costs for natural gas engines and natural gas fuel storage systems. The engines studied are the Cummins ISL-9G, a 9-liter, spark-ignited, stoichiometric engine, and the Cummins ISX-12G, a 12-liter engine which uses similar technology. These two engines

represent over 90% of the current MD/HD natural gas engine market for trucks. Both compressed natural gas (CNG) and liquefied natural gas (LNG) truck fuel storage systems were included in the study. The study also includes a brief survey of subsidies and tax advantages offered by local, state, and federal governments, as well as a survey of CNG and LNG fuel availability.

- **Section 6** presents the project conclusions.
- **Appendices.** The report includes four appendices, all of which should be reviewed during this peer review.
  Appendix A: Gasoline Engine Technology Combinations
  Appendix B: Diesel Engine Technology Combinations
  Appendix C: Vehicle Simulation and Vehicle Technologies
  Appendix D: Hybridization of Class 2b Pickup Truck (Argonne National Laboratory)

To provide comprehensive technical background on fuel efficiency technologies and costs studied, a final (not yet publically available) copy of Report #1 including its Appendices, and a draft copy of Report #2 and its Appendices are also provided for your reference. The folder labeled *Background Reference Material* contains these reports, which are being provided as reference materials only and do not need to be reviewed.

Additional supporting data files, engine maps/models, images, and materials may also be provided to reviewers upon request.

CHARGE QUESTIONS

While the research for SwRI report #3 was sponsored by NHTSA, it is important to note that the review document is an independent SwRI report that does not represent NHTSA's internal technical and economic analyses. Peer review comments should be directed to the content of SwRI Report #3 alone and not on policy related to past or planned federal rulemakings.

In your written comments, please provide a detailed response to all of the following questions that are within your area of expertise. Please also comment on additional topics as necessary to best apply your particular area(s) of expertise in evaluating this report. Your comments should be sufficiently clear and detailed to allow readers to thoroughly understand their relevance to this study. Comments should be limited to evaluation of the report as a stand-alone technical document and should not include unrelated commentary.

Section 1. Introduction

1-1. Does the introduction in Section 1 provide sufficient background on the overall program and the two prior reports in this series to allow this report to be read as a stand-alone document?

1-2. Does the introduction adequately detail the report contents?

Section 2. Combined Benefits Simulations

2-1. Please comment on Section 2. The purpose of this section was to explore which technologies provide benefits that are additive, which provide benefits that are not additive, and whether any technologies are synergistic, and to quantify the overall fuel consumption improvement from combining multiple technologies. Please comment on the quality, scope, and rigor of methodology used for the performance analysis of the vehicle and engine technology combinations (packages). Is the methodology clearly described and appropriate to the aims of the project? Is it sufficiently comprehensive and robust to provide credible results?

2-2. Were the technologies selected for the combinations appropriate, and were they logical pairings for the engines and vehicles simulated? If not, why not and what would you recommend?

2-3. Were the vehicles and drive cycles used in the study appropriate within the context of evaluating Class 2b-8 fuel consumption performance?

2-4. Were the computer models chosen appropriate for the analysis, and were they applied correctly to model vehicle and engine technology performance?

2-5. Are the assumptions used in the analysis reasonable? Why or why not?

2-6. Are the findings and conclusions adequately supported by the data? Describe any findings or conclusions that are not sufficiently supported. Describe any ways in which this section could be improved, as well as any additional key published data relevant to this review that should be included.

Section 3. Vehicle Parameter Sweeps

3-1. Please comment on Section 3. The purpose of the parameter sweeps was to gain an insight into the sensitivity of vehicle fuel consumption to the various parameters considered. Were the parameters chosen for the simulation sweeps realistic for the medium-duty vehicle segment?

3-2. Were the ranges used for each parameter in the sweeps appropriate?

3-3. Were the vehicles and engines used in the parameters sweeps appropriate?

3-4. Are the results plausible and well supported?

Section 4. Vocational Truck Fuel Consumption and Performance

4-1. Please comment on Section 4. The purpose of the analysis in this section was to explore the effect of vehicle specifications (explored in Section 3) on vocational truck fuel consumption and performance, as well as to consider the potential for a market shift towards gasoline power in the vocational segment. Are the discussions accurate and relevant to the subject matter?

4-2. Are the assumptions used in the payback discussions appropriate?

Section 5. Natural Gas Vehicle Cost Survey

5-1. Please comment on Section 5. The purpose of the analysis in this section was to describe a survey of current truck market costs for natural gas engines and natural gas fuel storage systems. Are the initial discussions accurate and appropriate?

5-2. Are the natural gas vehicle survey details correct, comprehensive, and sufficiently explained?

Section 6. Project Conclusions

6-1. Please comment on Section 6. The purpose of this section was to present project conclusions. Did this section effectively summarize the conclusions of each section of the report?

6-2. Did this section effectively present overall conclusions?

6-3. Are any important conclusions missing or inadequately explained?

Appendices

7-1. Please comment on the four report appendices. Do they provide sufficient technical detail in support of the report sections?

General Comments

8-1. Describe your overall assessment of the organization, readability, and clarity of this report, including any specific recommendations for improvement or changes needed.

8-2. Is the information provided in the report and appendices sufficiently detailed to thoroughly document all essential elements of the study? If not, what additional information is needed?

8-3. What are the strongest and weakest parts of this report? How can the weakest parts of the report can be strengthened?

8-4. Please provide any other comments you may have on this report.

Overall Recommendation

9-1. Based upon your review, indicate whether you find the report: (1) acceptable as is, (2) acceptable with minor revisions, (3) acceptable with major revisions, or (4) not acceptable. Please justify your recommendation. If you find the report acceptable with minor or major revisions, be sure to describe the revisions needed.

APPENDIX C

INDIVIDUAL REVIEWER COMMENTS

COMMENTS SUBMITTED BY

Matthew J. Barth, Ph.D.
Jacques and Eugene Yeager Families Endowed Chair; and
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Director, Center for Environmental Research and Technology
College of Engineering
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PEER REVIEW OF DTNH22-13-D-00298 – Task Order 0003, Report 3

"Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #3"
May 2015

Section 1. Executive Summary and Introduction

- The executive summary does a reasonable job of summarizing the overall report, but it is chock full of a lot of acronyms and defined "packages" that the reader really won't know about until they read the actual report. As such, the executive summary does not really stand on its own. It reads more like a conclusion after you read the whole report, as opposed to an executive summary that would let a layman know the gist of the report. I'm not sure if that is under the purview of this review.

1-1. Does the introduction in Section 1 provide sufficient background on the overall program and the two prior reports in this series to allow this report to be read as a stand-alone document?

- The introduction explains the "lay of the land" in terms of the NHTSA process and what the charge is leading to this report #3. It refers to report #1, in terms of updating the results and providing the relationship of this report #3 to the past report #1. However, there is very little mention of report #2 in the intro. Although we already know about Report #2 and what it is all about, a general reader of this report #3 might be wondering about it. A sentence describing it in the intro would help.
- The intro (and section 3) discusses the "sweeps" it does of different parameters in the simulations. This term seems to be a bit of jargon, in academic papers we often describe these as a "parameter sensitivity analyses". I think simply stating that a "sweep" is essentially a "sensitivity analysis" would be useful, and then continue to call it sweeps after that.
- Overall, the intro of report #3 is sufficient to allow for report #3 be read as a stand-alone document.

1-2. Does the introduction adequately detail the report contents?

- Although it isn't crucial, the intro doesn't say anything about the conclusions of section 6, nor does it mention the contents of the appendices. The intro simply drops off abruptly right after describing section 6. A few more sentences might help here.

Section 2. Combined Benefits Simulations

2-1. Please comment on Section 2. The purpose of this section was to explore which technologies provide benefits that are additive, which provide benefits that are not additive, and whether any technologies are synergistic, and to quantify the overall fuel consumption improvement from combining multiple technologies. Please comment on the quality, scope, and rigor of methodology used for the performance analysis of the vehicle and engine technology combinations (packages). Is the methodology clearly described and appropriate to the aims of the project? Is it sufficiently comprehensive and robust to provide credible results?

- In section 2, it is stated that "NHTSA and SwRI agreed on combinations of technologies", but little or no detail is provided on how these combinations were chosen. It would be good to explain what were the guiding principles involved in terms of figuring out what combinations would be best, or most likely. The choice of the combinations of technology is a very important step and very little is said about it. The reader is left wondering if there are other combinations that maybe made sense, and deserved some analysis.

- In the technology combinations, there are a lot of acronyms, which is fine, since they are defined in the acronym list early in the report. However, the authors I think abbreviate previous packages (e.g., P1, and P2) but the reader isn't exactly clear if this is the case. It would be good to simply say what is meant by P1, P2, etc…

- It is understood that the main purpose of this effort is to evaluate fuel economy improvements and reductions of GHG emissions. As such, GT-POWER and the associated simulation tools are sufficient to make a good determination, given the different assumptions that are made along the way. However, there is very little discussion on the tradeoffs between control of pollutant emissions and fuel economy savings. In addition to the fuel economy improvement rules by NHTSA, vehicle and engine manufacturers must also comply with pollutant emission regulations. GT-POWER and the associated simulation tools do not examine the pollutant side of the equation, so there is a bit of a concern that by implementing certain technologies (or combinations of technology) for fuel economy, what would the effect be on pollutant emissions? Combined fuel economy and pollutant emissions analysis would be more appropriate. But it seems that this is outside of the scope of the project.

- In terms of drive cycles, I think report #1 discusses how these certain cycles were selected, based on providing a good range of operations for the different vehicle types. However for simulation analysis, an interesting approach would be to examine *vehicle activity data* (i.e., real world trajectory data from subsets of these vehicles) from the vehicles in question, and then select and compare driving cycles that are representative of the vehicle activity data itself. The number of publically-accessible vehicle activity data sets is increasing rapidly and should be utilized if at all possible (e.g., NREL's activity database described at http://www.nrel.gov/transportation). Better yet, rather than use driving cycles at all, why not run entire vehicle activity datasets (appropriate for the vehicle technology) directly through the model(s)? The computational time of these models is not that severe, so processing all of these data should not take too much time. That way you skip any controversy regarding whether the driving cycles are representative or not.

- It is possible for the reader to determine which technologies provide additive benefits, which combinations do not, etc., by examining the data (tables and graphs). There is some commentary about the different combinations, but the report could be improved if a paragraph was inserted after each vehicle type (DD15, T700, etc.) that explicitly stated what technologies were additive, which combinations did not work well, etc. The descriptions provided only touch on specific combinations; but there isn't any analysis that talks about how the different combinations compare. (actually, this is done more so for the later vehicles types, e.g., F-650, etc., but not so much for the initial vehicle types)

- On page 19, there is a reference to the SuperTruck program, but little info is given. A reference should be provided…
- Minor issue: the figure 2.6 has the black baseline line at 1% rather than at 0%, not sure if that is a graphical problem or if that was done on purpose?
- Minor: on page 40, not sure why “Vehicle Technology Combinations” is capitalized;
- In table 2.20 on page 44, it isn’t clear why the “2019 ISB” is in there twice. Isn’t this the baseline that things are being compared to? Or is this the diesel comparison? This needs a bit more explanation in the text, it is confusing to the reader.
- For figures 2.23 and 2.24, why is the scale of the graph chosen to be 20%, when all of the percent savings are around 12% or less? The other graphs had better scaling, these figures seem different.
- Section 2.3.11 seems to be missing text that interprets the results of table 2.23. The different percent FC benefits are in the data, but there should be some text that interprets this. It would also be interesting to compare this to the other technologies discussed so far in the report.
- Overall, the methodology described in section 2 is for the most part clearly described and appropriate, with some caveats as described above. The results are sufficiently comprehensive and robust.

2-2. Were the technologies selected for the combinations appropriate, and were they logical pairings for the engines and vehicles simulated? If not, why not and what would you recommend?

- Overall, the technologies selected were appropriate and logical for the vehicle. As mentioned above, it was difficult to determine how these combinations were selected in the first place; it seems that they were selected by NHTSA and SwRI in an ad-hoc fashion. Nevertheless, they seem appropriate. It would be interesting to see some combinations of the hybrid technology (e.g., integrated starter/generator) with the other standard FC savings measures.

2-3. Were the vehicles and drive cycles used in the study appropriate within the context of evaluating Class 2b-8 fuel consumption performance?

- Yes, the vehicles and drive cycles were appropriate for this class of vehicles (see earlier comment about driving cycles)

2-4. Were the computer models chosen appropriate for the analysis, and were they applied correctly to model vehicle and engine technology performance?

- Yes, the computer models were appropriate for the analysis. Although many assumptions were made, they all seemed logical. The modeling results provided reasonable numbers and are very good for relative comparisons.

2-5. Are the assumptions used in the analysis reasonable?

- Yes, the assumptions are all reasonable.

2-6. Are the findings and conclusions adequately supported by the data? Describe any findings or conclusions that are not sufficiently supported. Describe any ways in which this section could be improved, as well as any additional key published data relevant to this review that should be included.

- In general, the conclusions are adequately supported by the data. However, this section needs a good wrap-up set of paragraphs that talks about the different results at a higher level. For example, how did all of the technology combinations compare across different vehicle platforms? What might be other technology combinations that were not explored? (e.g., the inclusion of mild hybridization with other standard FC saving technology).

Section 3. Vehicle Parameter Sweeps

3-1. Please comment on Section 3. The purpose of the parameter sweeps was to gain an insight into the sensitivity of vehicle fuel consumption to the various parameters considered. Were the parameters chosen for the simulation sweeps realistic for the medium-duty vehicle segment?

- I'm not sure why Figure 3.1 only shows the Cd values of 5% and 10%, where the other figures showed 5%, 10%, and 15%. Why was 15% left out?
- The general conclusions of aerodynamics are logical, the main effect occurs at higher and sustained speeds.
- On page 62, the sentence "The large frontal area of the T270 limits the portion of road load that comes from tire rolling resistance" needs more explanation… how does the frontal area limit the rolling resistance road load?
- For rolling resistance reductions, it should be mentioned that there might be other important less desirable implications such as lower traction, load distribution, etc.
- For the weight reduction, it is unclear how the different weight reduction values were chosen for the different vehicle types. The RAM pickup was studied at 300, 600, and 900 lbs. The F-650 was studied at 400, 700, and 1000 lbs. The T-270 was studied at 400, 800, 1200 lbs. Were these chosen based on a general percentage of the vehicle's overall weight?
- The section of axle ratios provides a good explanation of the strong tradeoff between fuel economy and torque required for heavy loads. It seems that torque performance requirements have to be met first, then adjusted for best fuel economy.
- It seems that the section on axle ratios (sections 3.4, 3.5, 3.6) has a lot more detail than the other parameters sensitivity analyses; although it is interesting, I'm not sure if it adds a lot to the report. As mentioned, you design a vehicle to meet certain performance specifications, and then you do what you can get improved fuel economy without affecting those performance specifications.

3-2. Were the ranges used for each parameter in the sweeps appropriate?

- Yes, the ranges are appropriate for all 4 different paramters

3-3. Were the vehicles and engines used in the parameters sweeps appropriate?

- Yes

3-4. Are the results plausible and well supported?

- Yes, the results are plausible.

Section 4. Vocational Truck Fuel Consumption and Performance

4-1. Please comment on Section 4. The purpose of the analysis in this section was to explore the effect of vehicle specifications (explored in Section 3) on vocational truck fuel consumption and performance, as well as to consider the potential for a market shift towards gasoline power in the vocational segment. Are the discussions accurate and relevant to the subject matter?

4-2. Are the assumptions used in the payback discussions appropriate?

- Section 4 is an interesting section, describing differences of different engine technologies and relative payoffs between diesel engines and gasoline engines with technologies. In the cost analysis on page 80, it is unclear how the authors came up with the assumption that the average engine cost difference was $9000. Earlier the report stated that emission control technology on diesels are a major part of the expense. However, very little is mentioned on the cost of the future FC savings technology that would be put on gasoline engines (e.g., package 16 and package 20 technology elements). Is that cost part of the $9000 difference assumption? I guess report #2 specified that cost elements of the different fuel savings technology. This report #3 should refer to this.

- Sections 4.2, 4.3, and 4.4 are all interesting, but somewhat disjointed. For section 4.4, it seems you could apply a driving cycle with a lot of stops and idle to calculate how much you could save with stop/start technology.

Section 5. Natural Gas Vehicle Cost Survey

5-1. Please comment on Section 5. The purpose of the analysis in this section was to describe a survey of current truck market costs for natural gas engines and natural gas fuel storage systems. Are the initial discussions accurate and appropriate?

5-2. Are the natural gas vehicle survey details correct, comprehensive, and sufficiently explained?

- Overall, this is a well written section on the issues of natural gas. The authors hit on all the key topics areas (and the tradeoffs), including engine and vehicle availability, size and weight penalties, engine, fuel, and vehicle prices, fuel availability, and government incentives. It is fairly complete, but it seems that the authors mainly discuss the general disadvantages of natural gas solutions, emphasizing less on the positives (better energy independence, lower GHG, etc.). The transit industry has successful used natural gas in their fleets, overcoming many of the points outlined in this section. I wonder if the authors could discuss a bit more on how it has been successful for transit, but may not be for the vocational trucks.

- Minor: on page 84, the hyphen of "-260 degrees" is on one line and 260 on the next, making it confusing what the temperature is.
- On page 84, the sentence "A slow fill happens at nearly constant temperature, so a loss in energy density does not occur" would be more correct if stated: "A slow fill happens at nearly constant temperature, so a loss in energy capacity does not occur."
- Page 86, the following sentence needs to be fixed: "The CNG system suffers a weight penalty of 2,100 pounds with full tanks, and 2,358 pounds with empty tanks…" I'm not sure where 2358 comes from, and also I think the words empty and full are switched…

Section 6. Project Conclusions

6-1. Please comment on Section 6. The purpose of this section was to present project conclusions. Did this section effectively summarize the conclusions of each section of the report?

6-2. Did this section effectively present overall conclusions?

6-3. Are any important conclusions missing or inadequately explained?

- Overall, the conclusions section is good. Just a few minor comments:
- On page 98, one conclusion is "Achieving this level of benefit requires the use of complex and expensive technologies that are not yet fully developed, such as a waste heat recovery system." In this report, nothing was mentioned about the cost of the technology, I assume that information is in report #2.
- The conclusions seem to only cover Sections 2 and 3; sections 4 and 5 are not really mentioned at all in the conclusions section. It would be good to at least have a few key conclusions about the natural gas vehicles.

Appendices

7-1. Please comment on the four report appendices. Do they provide sufficient technical detail in support of the report sections?

- Overall, the appendices cover a lot of details in terms of the vehicle technology combinations and their results. There is sufficient technical detail in these sections.
- It is clear that the appendix on the hybrid systems was written by different authors, the flow of that section is different, but adequate.
- Some of the tables and figures in the appendix are inconsistent in style and formatting, but the information content is adequate.

General Comments

8-1. Describe your overall assessment of the organization, readability, and clarity of this report, including any specific recommendations for improvement or changes needed.

- Overall, the report is well organized and pretty clear. Just a few comments:
- As mentioned earlier, the executive summary makes a lot of assumptions in terms of what is already known, therefore it may have limited use as a stand-alone document.
- Some of the different sections in the report end abruptly, without any concluding sentences which sometimes leaves the reader hanging.
- In the discussions about all of the different technology combinations it gets confusing in terms of what the baselines are. All the information is there, however it is necessary to read some sections a few times before it sinks in.

8-2. Is the information provided in the report and appendices sufficiently detailed to thoroughly document all essential elements of the study? If not, what additional information is needed?

- There is sufficient detail in the report, both in the main body and in the appendices. But sometimes you need to track multiple things between sections (and tables) of the report, and the appendices to fully understand the details. This is mainly due to the complexity of the analysis.
- As mentioned previously, it is not clear to the reader how the different combinations of technologies were chosen, it seems somewhat ad-hoc in some cases. The reader is left wondering if other technologies could also be woven in, such as different types of hybridization.

8-3. What are the strongest and weakest parts of this report? How can the weakest parts of the report can be strengthened?

- The strongest part of the report was section 2, in terms of the analysis and comparison of the different technology combinations. Sections 4 and 5 were both written very well and covered the key areas of costs and tradeoffs. The weakest part of the report probably was the executive summary which probably doesn't do too well as a stand-alone document, it is really just a summary that you can understand once you have read the entire report.

8-4. Please provide any other comments you may have on this report.

Overall the information provided in the report is sufficiently detailed; various comments on specifics have been provided above.

- As mentioned as part of the evaluations of Report #1, one key thing that would be helpful in the introduction is some better scoping sentences. Fuel economy is affected by a number of different things, generally categorized into four areas: 1) vehicle technology effects; 2) vehicle fuel effects; 3) driver behavior effects; and 4) roadway infrastructure effects. Obviously this report deals with the area of 1), i.e., what kind of on-board vehicle technology exists that can improve fuel economy. Even though it is out of the scope of the report, different fuels and fuel additives have an effect on fuel economy, there is significant research and products in this area. Regarding 3), there is now technology that affects how a driver operates the vehicle. Example of this technology include eco-driving aids and real-time navigational aids showing roadway status (e.g., upcoming grade, traffic, etc.). In a sense, this driver feedback technology changes the “driving cycle” that is applied to the vehicle in a typical testing environment. When employed, this eco-driving feedback technology allows for different levels of fuel economy savings, see DOE vehicle technology program references (e.g., see http://energy.gov/sites/prod/files/2014/07/f17/vss087_verma_2014_o.pdf and http://energy.gov/sites/prod/files/2014/12/f19/2014_amr.pdf). Again, this should at least be mentioned maybe in the introduction. Regarding 4), there are roadway infrastructure and traffic operation techniques that can also affect vehicle fuel economy. These include things like traffic signal synchronization, variable speed limit techniques on freeways, adaptive ramp metering, etc. Although this is not vehicle technology per se, this roadway technology can improve overall traffic fuel economy. Again, this is outside the scope of this report, but perhaps it should still be mentioned in the introduction.

Overall Recommendation

9-1. Based upon your review, indicate whether you find the report: (1) acceptable as is, (2) acceptable with minor revisions, (3) acceptable with major revisions, or (4) not acceptable. Please justify your recommendation. If you find the report acceptable with minor or major revisions, be sure to describe the revisions needed.

- Based on my review, the report and appendices are acceptable with minor revisions. There are a variety of comments and suggestions made in the above text that the authors could address.

COMMENTS SUBMITTED BY

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Director of Engineering
WM International Engineering, LLC
Darien, Illinois

PEER REVIEW CHARGE

DTNH22-13-D-00298, Task Order 0003: Report 3

"Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #3"

Section 1. Introduction

1.1. Does the introduction in Section 1 provide sufficient background on the overall program and the two prior reports in this series to allow this report to be read as a stand-alone document?

The introduction is rather brief. It is recommended that Section 1 be expanded to:

- Include a description of the "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles". This may be done via table (see below). The text could include applicability: combination tractors, vocational vehicles, HD pickups and vans. May also for completeness includ US EPA SmartWay requirments (tractor and trailer aerodynamics, low rolling resistance tires) and applicability (53' or longer trailers or box type). It may also include motivation (improved emissions and fuel savings via adoption of new technologies, harmonize standards). Finally, a timeline for adoption may be included.

HD Combination Tractor Vehicle Standards (gCO2/ton-mile)						
	2014-2016 MY			2017 MY and beyond		
	Class 7	Class 8		Class 7	Class 8	
		Day Cab	Sleeper Berth		Day Cab	Sleeper Berth
Low Roof	107	81	68	104	80	66
Mid Roof	119	88	76	115	86	73
High Roof	124	92	75	120	89	72

Vocational Vehicle CO2 Standard (gCO2/ton-mile)			
	LHD Class 2b-5	MHD Class 6-7	HHD Class 8
2014 MY	388	234	226
2017 MY	373	225	222

Final HD Diesel Engine Standards (gCO2/bhp-hr)					
	LHD (2b-5)	MHD (Class 6-7)		HHD (Class 8)	
		Vocational Veh	Tractors	Vocational Veh	Tractors
2014-2016 MY	600	600	502	567	475
2017 and Later	576	576	487	555	460

- Include a summary of the engines and vehicles per Table 3.1 VEHICLE AND ENGINE CLASSIFICATION from Report 1 (page 32), as noted below.

TABLE 3.1 VEHICLE AND ENGINE CLASSIFICATION

Class	Vehicle	Diesel	Gasoline	Base Transmission
2b	Ram Pickup	Cummins 6.7 Liter 385 HP (base), 4.5 Liter 256 HP	3.5 L V-6, 6.2 L V-8	6-Speed Automatic
3				
4				
5	F-650 Tow Truck	Cummins 6.7 Liter 300 HP (base), 4.5 Liter 256 HP	3.5 L V-6, 6.2 L V-8	5-Speed Automatic
6	T270 Box Truck			
7				
8	T700 Tractor-Trailer	Detroit 14.8 L DD15 (base), 12.3 L Derivative	None	10-Speed AMT

- Present the major findings from Report 1 (list the technologies examined, highlight which technologies made it to this stage of the study);
- Report 2 is a cost estimate study. It is not clear what role this has played in the down-selection process. If it has, please indicate how it did.

1.2. Does the introduction adequately detail the report contents?

Yes. The report has a brief but informative summary of the sections that follow.

Section 2. Combined Benefits Simulations

2-1. Please comment on Section 2. The purpose of this section was to explore which technologies provide benefits that are additive, which provide benefits that are not additive, and whether any technologies are synergistic, and to quantify the overall fuel consumption improvement from combining multiple technologies. Please comment on the quality, scope, and rigor of methodology used for the performance analysis of the vehicle and engine technology combinations (packages). Is the methodology clearly described and appropriate to the aims of the project? Is it sufficiently comprehensive and robust to provide credible results?

The section is well organized. Tables describe technology combinations for each engine and vehicle. This reviewer has checked the references between tables and descriptions. The report is very clear. There are only minor cases where there could be more clarity. Here may be one case: In some instances the report indicates the complexity of the packages assembled. Package 5 in page 16 is deemed very complex but it is not clearly indicated why. This particular package however may not be as complex however as packages 3, 3a, 3b… 3f that incorporate WHR. The report may want to capture the complexity of each of the packages (see suggestion below).

The methodology is adequate. It is comprehensive and the work presented provides credible results. The systematic approach of stepping through "package" scenarios is very organized and easy to follow.

Please update and correct the following typos:

- Table 2.7, 2.8, 2.9 have wrong reference to packages.
    - Table 2.7 P8: P2 + … should have been P7 +
    - Table 2.7 P9: P3 + … should have been P8 +

  - Table 2.8 P13: P2 + … should have been P12 +
  - Table 2.8 P15: P3 + … should have been P13 +, also +800 should be +700
  - Table 2.9 P17: P2 + … should have been P17 +
  - Table 2.9 P20: P3 + … should have been P18 +

- Page 10 states that cycles of Table 2.10 are described in detail Appendix C. This does not appear to be the case. The reader expects time traces of speed and load. Can these be inserted?
- Page 25 *2.3.5.9 3.5 V6 Package 18: Package 1 (should be 16) + Lean Burn (3.5 P18)*
- Page 26 *2.3.5.12 6.2 V8 Package 21: Package 1 (should be 20) + VVA (6.2 P21)*
- Page 28, package numbers 2-5 seem mislabeled, they start at 11
- Page 35-36. Figure titles refer to F-650 *(should be T270)*
- Page 50. Reference made to F-650 in section *2.3.9.17 Comparison of the Three Baseline Engines in the F-650* need to be corrected *(should be Ram pickup truck)*

Suggested improvements: The data may be rearranged to show more clearly the merit of each the technologies and the result of combinations. One way is illustrated in the figure below for the HD DD15 engine and the T700 vehicle, and later for the engines and F-650 vehicle. The tables seeks to:

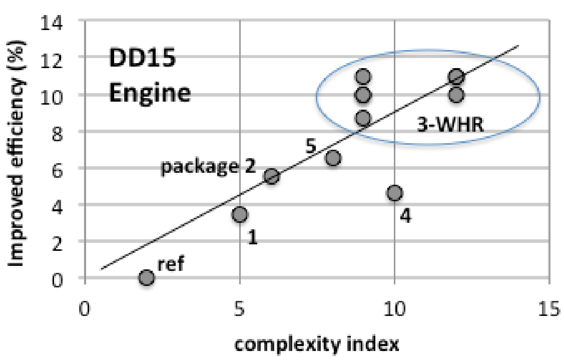
- Clearly highlight the technology content of each package and provide a better overview of the combinations,
- Put a complexity weight factor for each package alongside the reported fuel benefit. Here GREEN=1, YELLOW=2, RED=3 (the designations are the reviewer's estimations and are inserted primarily for illustration purposes).
- Charts may be drawn indicating the relation between the fuel and complexity index such as indicated below.
- The tables are drawn for one of the drive cycles (NESCAFF for the HD and WHVC for the MD – each at 50% load).

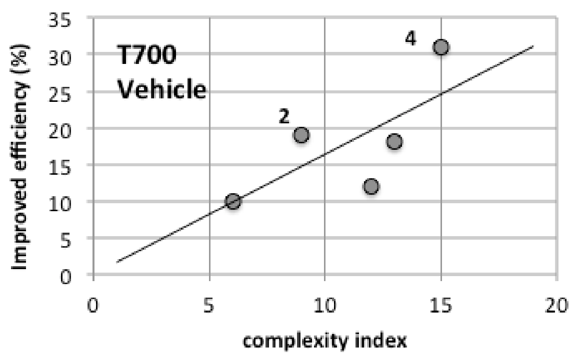
Suggestions on analyzing HD simulation data

Results shown for NESCAFF – 50% load

DD15 Engine Technologies in T700												
Package	Combustion	Turbocomp	Turbochg	EGR	SCR	flow restrict	FMEP	Downspeed	WHR	WHR-Recup	NESCAFF	Complexity
2011	-	base	Asymetric	base	base	base	base	1368			-2.4	
2019	1%	none	Asymetric	base	base	base	base	1368			0.0	2
1	1%	none	Asymetric	base	base	base	10-35%	1368			3.4	5
2	1%	none	Asymetric	base	base	base	5-17%	1051			5.5	6
3	1%	none	Asymetric	base	base	base	5-17%	1051	Water	-	10.0	9
3a	1%	none	Asymetric	base	base	base	5-17%	1051	R245	-	8.7	9
3b	1%	none	Asymetric	base	base	base	5-17%	1051	R245	x	10.0	12
3c	1%	none	Asymetric	base	base	base	5-17%	1051	MeOH	-	11.0	9
3d	1%	none	Asymetric	base	base	base	5-17%	1051	MeOH	x	11.0	12
3e	1%	none	Asymetric	base	base	base	5-17%	1051	EtOH	-	10.0	9
3f	1%	none	Asymetric	base	base	base	5-17%	1051	EtOH	x	11.0	12
4	1%	none	Fix	None	high Eff	base	10-35%	1368			4.6	10
5	1%	base	Asymetric	base	base	reduced	5-17%	1051			6.5	8

T700 Truck Technology Combination Results												
	Cd	Crr	Weight	AC power	Chassis fric	Axles	Transm	Engine	SCR	WHR	NESCAFF	Complexity
	base	base	base	base	base	base	base	base	base	none	0.0	0
1	-15%	-10%	3%	base	base	base	base	base	base	none	9.9	6
2	-25%	-30%	-6.50%	base	base	base	base	base	base	none	19.0	9
3	-15%	-10%	3%	-40%	-20%	6x2	18-AMT	base	base	none	12.0	12
4	-25%	-30%	base	-40%	-20%	6x2	18-AMT	DD15-3b	base	install	31.0	15
5	-15%	-10%	3%	-40%	-20%	6x2	18-AMT	DD15-5	high eff	none	18.0	13



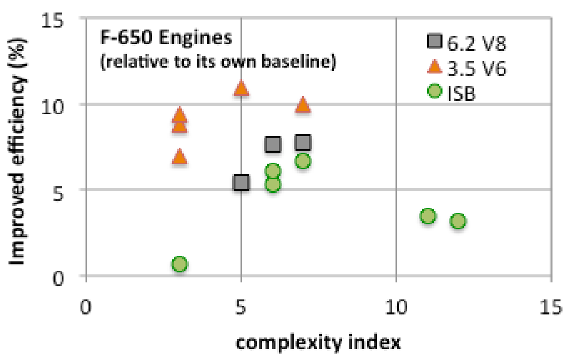


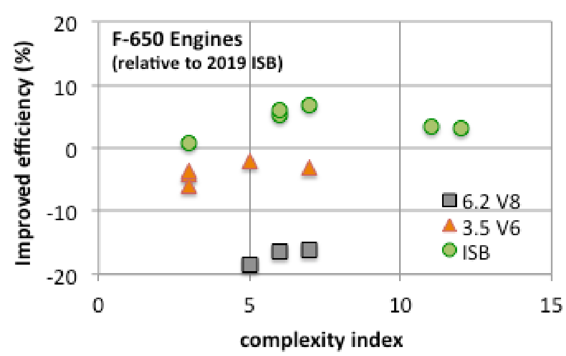
Suggestions on analyzing MD simulation data

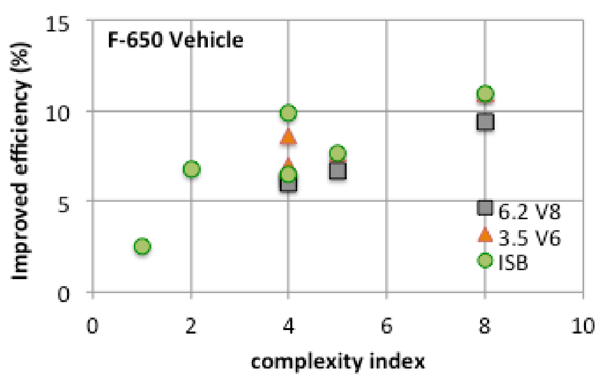
Results shown for WHVC – 50% load

F-650 Engine Technologies													
Package	**Engine**	**Combustion**	**Turbochg**	**EGR**	**SCR**	**VVA**	**Cyl Deactiv**	**FMEP**	**Downspeed**	**Downsize**	**WHVC-rel**	**WHVC-net**	**Complexity**
2013	ISB	-	base	base	base	none	-	-	2500	-	-3.8	-3.8	
2019	ISB	1%	base	base	base	none	-	5-17.5%	2500	-	0.7	0.7	3
6	ISB	1%	2.5%	base	base	none	-	5-17.5%	2200	-	6.7	6.7	7
7	ISB	1%	5.0%	None	high eff	none	-	10-35%	2200	-	3.2	3.2	12
8	ISB	1%	5.0%	None	high eff	none	-	5-17.5%	2200	-	3.5	3.5	11
9	ISB	1%	2.5%	base	base	none	-	10-35%	2500	-	5.3	5.3	6
10	ISB*	1%	base*	base*	base*	none	-	base*	3000	4 cyl	6.1	6.1	6
16	3.5 V6	stoich	base	base EGR	-	VVA	-	-	5500	-	8.8	-4.2	3
17	3.5 V6	stoich	base	base EGR	-	VVA	-	-	4000	-	11.0	-2.0	5
18	3.5 V6	Lean	base	base EGR	-	-	-	-	5500	-	7.0	-6.0	3
19	3.5 V6	stoich	base	base EGR	-	-	-	-	4000	-	9.4	-3.6	3
20	3.5 V6	GDI	base	base EGR	-	-	Cyl Deactiv	10%	5500	-	10.0	-3.0	7
21	6.2 V8	GDI	base	base EGR	-	VVA	Cyl Deactiv	10%	5500	-	7.8	-16.2	7
22	6.2 V8	GDI	base	base EGR	-	2-Phasers		10%	5500	-	7.7	-16.3	6
23	6.2 V8	GDI	base	base EGR		-	Cyl Deactiv	-	5500	-	5.4	-18.5	5

F650 MD Truck Technology Combination Results													
	Cd	**Crr**	**Weight**	**AC power**	**Idle-N**	**Transm**	**ISB**	**3.5 V6**	**6.2 V8**		**WHVC**		**Complexity**
	base	base	base	base	-	5-speed AT	0.0				0.0		0
11	15%	-			-	5-speed AT	2.5				2.5		1
11	-	30%			-	5-speed AT	6.8				6.8		2
12	-	20%				8-speed AT	6.5				6.5		4
		20%				8-speed AT		7.0			7.0		4
		20%				8-speed AT			6.2		6.2		4
13	-	20%			Idle-N	8-speed AT	7.7				7.7		5
		20%			Idle-N	8-speed AT		7.7			7.7		5
		20%			Idle-N	8-speed AT			6.7		6.7		5
14	-	20%				6-spd AMT	9.9				9.9		4
		20%				6-spd AMT		8.6			8.6		4
		20%				6-spd AMT			6.0		6.0		4
15	-	20%	700lb	40%	Idle-N	8-speed AT	11.0				11.0		8
	-	20%	700lb	40%	Idle-N	8-speed AT		11.0			11.0		8
	-	20%	700lb	40%	Idle-N	8-speed AT			9.4		9.4		8







2-2. Were the technologies selected for the combinations appropriate, and were they logical pairings for the engines and vehicles simulated? If not, why not and what would you recommend?

Yes, overall the combinations chosen are well thought out. There is no “formal” justification for the packages, but this is reasonable as there are informative discussions imbedded in each package results discussion.

2-3. Were the vehicles and drive cycles used in the study appropriate within the context of evaluating Class 2b-8 fuel consumption performance?

Yes, the cycles are appropriately chosen for each vehicle configuration.

- The cycles selected allow an understanding of how different engine and vehicle technology combinations perform across a range of applications through the drive cycle selection. The study considers too sensitivity to payload. The choice of 3 payloads provides sufficient resolution for weight impact.
- The HD, MD T270 and F-650, and the Ram Pickup engine and vehicles use a different set of cycles given the nature of the application. He process is well thought out as shown in the Ram Pickup cycles. This category accounted for an empty truck, 50% of the maximum payload in the cargo bed (8,500 lbs) but no trailer (ALVW), and with trailer (25,000 lbs). The latter case accounts for the frontal area increased by 50% to account for the aerodynamic drag of the trailer.

Items that are unclear to this reviewer:

- The choice of multiple WHR options seems disproportionate (e.g. multiple fluids). Overall 7 iterations are presented out of 11. They all point to the same conclusion (high efficiency). The discussion needs to consider the impact of fluids from the perspective of safety (EtOH, MeOH are highly flammable, water will have to cope with freezing).
- On the other hand, only one turbocompounding option is presented.

2-4. Were the computer models chosen appropriate for the analysis, and were they applied correctly to model vehicle and engine technology performance?

The GT-POWER tools used are proven and widely used in the industry for engine modeling. The base models are calibrated with experimental data. The authors do a very nice job to include test heat release data, actual turbocharger maps (or scaled maps). EGR and AFR are controlled to match the baseline engine. The Appendices give comprehensive maps of the more important modeling parameters, including well resolved maps of the fuel consumption. Vehicles and vehicle technologies were modeled using SwRI’s Vehicle Simulator, a proven tool. The Vehicle Simulator tool can handle the range of vehicle technologies studied here.

For clarity as a stand along publication, Report 3 may want to include the definition of the term “Fuel Savings” (as was done in Report 1).

2-5. Are the assumptions used in the analysis reasonable? Why or why not?

Yes. The report does a good job indicating the assumptions used and their rational. Some examples include:

- Good description of the pumping work and its role in engine efficiency,
- The distinction between FMEP (cylinder kit, bearing, valve train friction, fuel, oil, and water pumps, piston cooling nozzle) and accessory (not essential to engine operation such as AC compressor, alternator, power steering pump, air compressor, and engine cooling fan),
- When presenting vehicle package P4, containing the DD15 P3b with WHR, the report is cautious to not add weight reduction,
- The report notes the challenge of adapting existing SCR units on lean burn gasoline engine to reduce NOx owing to the large exhaust temperatures,
- The modeling takes into account Idle-neutral features and the characteristics of the larger geared automatic s and the AMT transmissions. These are well documented in the Appendix.

Clarifications needed:

- Page 34, Engine Technology for the T270, “The same engine technology combinations have been evaluated in two different medium duty vocational trucks” seems redundant given the previous statement before it and it reads like there is two T270 trucks under study.
- Page 37-38. The comparison between the T270and F-650 is very useful. The discussion on the ISB is very clear, but no so with the V6 and V8 engines. The text regarding the rich-operation (it is stated to be more efficient) is not expected.
- There is a potential source of confusion in the results for the **MD Vocational Truck and the Pickup Truck Engine and Vehicle Technology Combinations**. Results are shown in terms of <u>percent fuel consumption reduction compared to each engine’s baseline projected 2019 configuration</u>.
    - o In addition to the benchmarks provided, **results would be more useful if expressed in % fuel savings with respect to one common reference.** This is done only briefly in the conclusion for a brief sample of the cases considered. *The report does addresses the differences between baseline engines, such as in Figure 2.7. The dependence on cycles is shown at 50% payload. Here shows that the V6 gains approximately 11% (varies with cycle) and the ISB gains approximately 24% (varies with cycle) over the V8 baseline.*
    - o The report uses the “ISB 2019” as baseline for the technology comparison. This effectively means that the V6 entries (P16-P19) and V8 entries (P20-P24) have a 13% and 24% fuel deficit respectively. *The report does indicate that Diesel has a 13% fuel consumption advantage over the gasoline engine due to the energy differences for the same volume.*
    - o Overall, comparing to one same reference would add clarity.
    - o Costs, durability, need be considered such as with an efficiency vs. cost tradeoff.

- ISB package 10 is difficult to follow. The downsizing, remake of the lug line of the engine, and the vehicle axle ratio modifications makes this entry significantly different than the others. This same package retains EGR.

- Same ISB package 10 could have considered SCR.

2-6. Are the findings and conclusions adequately supported by the data? Describe any findings or conclusions that are not sufficiently supported. Describe any ways in which this section could be improved, as well as any additional key published data relevant to this review that should be included.

Yes. The findings are highly coupled to the simulation work performed.

- The report does a good job to tie in the work and performance results from the Supertruck program when considering the more technologically aggressive packages on the T700 vehicle.

- There are some very good insights in the report that may not be readily known:

  - The downspeed option (ISBP 6 and ISB P8) show a slight and rather large fuel penalty on the CARB and Parcel drive cycles. The report indicates that the higher torques at lower rated speeds will require tighter torque match to reduce the fuel requirement when vehicle is stationary.

- This reviewer found the comparison section *2.3.7.1 Comparison of engine technology results between the T270 and F-650* particularly useful as it provided a good summary of the technologies and how they related to the results found in the report.

Suggestions:

- The “state-of-the market” discussion on *2.3.11 Hybrid System Results* is brief but informative. The results of the simulation (performed by Argonne) is shown. Further discussion may place these results in the context of the engine and vehicle: asses at least qualitatively if not quantitatively the efficiency vs. cost/complexity that this option provides; highlight barriers to overcome the poor payback and the technical challenges to migrate the technology to the MD-HD sector.

Clarifications needed:

- In section *2.3.2.12 DD15 Technology Package 5: Packaging the reduced restriction intake, exhaust, and charge air cooler systems in a practical vehicle would prove very difficult.* Please explain why.

Section 3. Vehicle Parameter Sweeps

3-1. Please comment on Section 3. The purpose of the parameter sweeps was to gain an insight into the sensitivity of vehicle fuel consumption to the various parameters considered. Were the parameters chosen for the simulation sweeps realistic for the medium-duty vehicle segment?

The study selects aerodynamic drag coefficient (Cd), tire rolling resistance coefficient (Crr), axle ratio and vehicle empty weight as the parameters for study. This section focuses on single parameter sweeps, unlike the earlier section that focuses on combination technology packages. These parameters are important for the MD vehicle performance.

Section 3 could be enhanced by:

- Indicating that the results in Sect 3.1 (aerodynamic sweep) may be referenced to Section 2. The results for Fig 3.1 were presented in page 52 for P16, for Fig 3.2 in page 29 for P11 , and for Fig 3.3 in page 39 for P6.
- Improve consistency in the report: Package P16 is noted in Fig 3.1, but P11 and P6 are not in the following Fig 3.2 and 3.3.
- Improve consistency in the report: Table 3.1 lists the max percent grade in top gear, even when downshifted take place. The following Tables 3.2, 3.3 don't. Similarly Table 3.2 shows Gear Bound entries, but Table 3.3 does not (ISB 6.89 AR entry).
- Providing a summary on the overall contribution of aero, rolling resistance, AR and weight that compare one with respect to the others.

Typos and possible corrections:

- Page 59-63. The results for **Cd and Crr sweeps** as shown in the figures appear to scale (the relative size of the Fuel Savings bars are same across cycles as the sweep takes place). This seems to imply that Cd or Crr impacts on vehicle drag and friction does not change across drive cycles (but these have wide ranges of speeds and accelerations). Could these results be checked?
- Page 62. On the F-650 and T270 trucks, the largest fuel savings comes at 55 MPH, with the second largest benefit at 65 MPH (figures show it is WHC instead – though most cycles are relative same with exception of the Parcel).
- Page 65 Fig 3.10, title Ram P2 (should it be P17).

3-2. Were the ranges used for each parameter in the sweeps appropriate?

The ranges are appropriate.

Suggestions:

- The report could gain if it provided a short description on what features would be responsible for the magnitude of the sweeps. For example, Cd% reduction range per each vehicle category (roof deflectors, fuel tank fairings, box skirts, mirrors). Same could be done for Crr% reduction. Maybe a reference could be inserted here such as ***Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles (National Academies Press, Jul 30, 2010).*** Similarly, a justification for the weight reduction quantities can be given.
- The results presented under the Ram Axle Ratio Sweep, when comparing the engine configurations, adjusts the gasoline engine axle ratios to a shorter setting (higher AR value) to match the towing capability. However, the figures in the section represent simulations at ALVW (much lower load). *This*

may be okay as tater in the section, the study takes up the effect of AR on grade performance, and here the effect of AR is seen at the higher payload - GCW.

3-3. Were the vehicles and engines used in the parameters sweeps appropriate?

Yes, the vehicles and engines chose were appropriate.

3-4. Are the results plausible and well supported?

The results are reasonable. The methodology used in the simulation follows the same approach as in Section 2. Results are well organized and discussed.

Section 3 highlights or re-emphasizes what may be an important question for future regulations:

- The fuel economy gains for individual technologies are very dependent on the drive cycles.
- How can the regulatory body and manufacturers work to better align regulatory cycles to real-world applications and thus encourage technology packages such as the ones discussed in the Report?

Section 4. Vocational Truck Fuel Consumption and Performance

4-1. Please comment on Section 4. The purpose of the analysis in this section was to explore <u>the effect of vehicle specifications</u> (explored in Section 3) on vocational truck fuel consumption and performance, as well as to consider the potential for a market <u>shift towards gasoline power</u> in the vocational segment. Are the discussions accurate and relevant to the subject matter?

This section focuses on the overall merits of Diesel vs. gasoline fueled engines in the vocational sector. The section, provides a brief and informative description of the Diesel and gasoline presence in the MD market since 1994. Important shifts are highlighted, such as the large price differential between the Diesel and gasoline exhaust after-treatment devices. The cost added of the Diesel option on F-650 is revealing, and is explained with the added aftertreatment devices, fuel injection system and base engine.

Fuel consumption benchmarks are provided for the T270 vehicle for the baseline Diesel engine and a selected technology package for the V6 and V8 gasoline engines. *The report could also make reference to the baseline engine comparison provided in Section 2 for the F-650 (Fig 2.7, page 28).*

The analysis then continues to examine a payback analysis and results are summarized in Table 4.2. Overall the presentation is clear and informative. The analysis makes a powerful case for gasoline, unless the Diesel engine can contain the cost differential.

The discussion on vehicle specifications is limited to a brief discussion on vehicle power demand and a review of the aero, rolling resistance and weight analysis from Section 3. The Charter indicates that a comprehensive "specification sheet" be drawn up. One interpretation is a table with one dimension describing specifications and the other attributes. This work can be of considerable magnitude and may be beyond the scope of the current Report. Nonetheless, the interpretation may be to provide a table as shown below, where for weight the technology specification may be highlighted given the vehicle specification.

Sample of "effect of vehicle specification"

							Vehicle features				Engine features				
Requirements	PWR/TQ	Axle Ratio	Body (Style)	Frame (Weight)	Transmission	Fuel Type	Aero	Crr	Idle Neutral	…	FMEP	Cyl Deactivation	VVA	Downspeed	…
Towing															
Grade															
Distance travel															
Drive Cycle															
Maneuverability															
Visibility															
…															

4-2. Are the assumptions used in the payback discussions appropriate?

The assumptions made for the payback analysis are adequate. The assumptions include reasonable ranges for the baseline cost of gasoline fuel and the cost differential between gasoline and Diesel. Though not clearly specified, there is reference to the life of the vehicle which helps frame the payback results (12-15 years).

Section 5. Natural Gas Vehicle Cost Survey

5-1. Please comment on Section 5. The purpose of the analysis in this section was to describe a survey of current truck market costs for natural gas engines and natural gas fuel storage systems. Are the initial discussions accurate and appropriate?

This survey is very informative. The report on natural gas begins with a clear motivation of lower fuel price, lower carbon content leading to lower GHG emissions, and government subsidies. *It may be noted that many municipalities are requiring NG vehicles (in some cases they require from a manufacturer a percent of vehicles to be purchased be NG).*

The report outlines important issues regarding the adoption of natural gas vehicles. *These issues are very important. One personal experience in this area entails following the introduction of natural gas buses in a major municipality in Europe – today operating over 900 natural gas buses in addition to 1200 Diesel buses. The municipality took several years to attain "smooth running". Many of the issues they struggled with are contained in this Section. One issues not mentioned in the report that could be included is safety – in this* *municipality, the use of natural gas vehicles was restricted to operate above ground. All bus routes that used tunnels were assigned to Diesel buses.*

The report could also include estimates of fill in times. *These may be 25 GGE/hr (with 58 SCFM IR compressor) and up to 50 with accumulator-equipped stations (per experience from 2010-2012 time frame).1*

Point of Clarification

The following fou references were provided:

1. *Terrón, Juan; Director de Ingenieria. *Experiences of the EMT on Alternative Fuels.* Nov 2010, Second Open Conference on Energy Directives of the City of Madrid. http://www.madrid.es/UnidadWeb/Contenidos/EspecialInformativo/MedioAmbiente/EnergiaCambioClimatico/06EventosJornadas/IIJornActEn/EXPJORNACT.pdf

   **EMT is the Empresa Municipal de Transportes - Municipal Bus Company of Madrid. The report outlines the municipality's conversion plans and progress from Diesel to clean and renewable fuels. Today they operate 1000 natural gas buses, nearly 50% of the fleet. The report is in Spanish but the reader should be able to pick up most of the information.*

2. Bauer Compressors, Inc.; *High Pressure Compressors for Natural Gas Vehicle Refueling* http://www.bauercomp.com/sites/default/files/upload/pdf/CNG_Brochure.pdf

3. CenterPoint Energy; *Natural Gas Vehicles (NGV) and Fueling Options*. 2nd Annual Natural Gas Vehicle Fleet Summit Conference & Exhibition; February 24-26, 2013, Houston http://www.centerpointenergy.com/staticfiles/CNP/Common/SiteAssets/doc/NGV_Feb_2013_Webinar.pdf

4. U.S. Department of Energy, *Costs Associated With Compressed Natural Gas Vehicle Fueling Infrastructure*. September 2014 http://www.afdc.energy.gov/uploads/publication/cng_infrastructure_costs.pdf

The report has a very good presentation on weight tank. The report shows a natural gas engine and vehicle offerings in Vehicle Classes from 2a through 8. This is accompanied by survey of natural gas vehicle and natural gas storage system prices.

5-2. Are the natural gas vehicle survey details correct, comprehensive, and sufficiently explained?

Yes, the survey appears accurate. It is comprehensive and well explained.

The sensitivity of pump prices to raw fuel prices from Table 5.7 seemed surprising, specifically the higher % increases for gasoline and Diesel vs. natural gas, but the numbers check. It highlights the impact of a low base cost for the natural gas fuel.

1 After submitting final comments, NHTSA requested from the reviewer any additional references that the reviewer could provide to NHTSA on this point. The reviewer's response has been inserted under *Point of Clarification*

The reporting fuel efficiency by Paper Transport and Kroger are important "real-life" reference data. *It may be worth inserting these vehicle configurations on the SWRI model tool to study the breakdown of the losses. The natural gas vehicles are reported as having less aerodynamic profiles, weight increase and worse than Diesel efficiency. This could be a good "case study" to be included in the report.*

Section 6. Project Conclusions

6-1. Please comment on Section 6. The purpose of this section was to present project conclusions. Did this section effectively summarize the conclusions of each section of the report?

Conclusions should identify technology segments for regulators, OEMs, Tier I suppliers, and in general consumers that will positively impact fuel savings while meeting current or future emissions standards. The conclusions, at least should point to specific technologies that merit further investigation. The report does this.

Conclusions appear they could be more focused. The authors may want to see if they can be made more specific, possibly more systematic, breaking them down by category, and including some evaluation regarding the complexity or risk (such as indicated earlier in Section 2).

6-2. Did this section effectively present overall conclusions?

Tables 6.1 and 6.2 are rather difficult to follow.

- Section 2 focuses on % savings with respect to each engine baseline.
- Here we have a comparison of the gasoline engines with respect to the Diesel. The numbers should readily come out from the previous tabulated results but they don't. I would strongly suggest that this be done: reference what tables in Section 2 are used to obtained the numbers shown.

6-3. Are any important conclusions missing or inadequately explained?

The Conclusion Section lacks a description of synergies among technologies. Conclusions could include what technologies work well with one another, and which do not. This was emphasized in the Charter and would be important to include.

The report establishes other fuel savings opportunities that were not able to be included in Report 3, such as reduced cooling fan power demand and improved efficiency of engine driven accessories such as hydraulic systems. It is good that this be pointed out and hopefully can be taken up in the future in a similar study.

Fuel savings are highly dependent on duty cycles. The report makes a strong case that vehicle and engines need to be well matched given the application. As in the case of the pick-up market, the installation of the 385 HP and 850 lb-ft Diesel engine is not needed unless trucks operate near GCW – whence it is important. The use of the downsized V6 provides significant fuel savings.

Appendices

7-1. Please comment on the four report appendices. Do they provide sufficient technical detail in support of the report sections?

Yes. They provide very good technical background to the sections of the report both for engine and vehicle (which includes a strong section on axle, governor speed and engine alternatives), and hybrid technologies.

General Comments

8-1. Describe your overall assessment of the organization, readability, and clarity of this report, including any specific recommendations for improvement or changes needed.

The report is very well organized, it reads well and is clear.

- The simulation of combined technologies is very complete. The report relies on a strong and systematic modeling approach,
- The cycles, vehicle, and engines chosen are very representative and adequate to fulfill the task.

8-2. Is the information provided in the report and appendices sufficiently detailed to thoroughly document all essential elements of the study? If not, what additional information is needed?

Yes, the report is technically very detailed and is accompanied by informative Appendices.

The addition of the following items may strengthen the report:

- Incorporate a summary of GHG Emission and Fuel Efficiency standards,
- Fuel saving estimates complemented with a cost-risk “complexity index”,
- The Conclusion Section should detailed the sources for the results shown on Tables 6.1 and 6.2.

8-3. What are the strongest and weakest parts of this report? How can the weakest parts of the report can be strengthened?

The simulation, technology-packages description and discussions are very strong.

- The cycles selected highlight how different engine and vehicle technology combinations perform across a range of applications. Results illustrate how some technologies are sensitive to payload in a given drive cycle,
- The report clearly indicates and justifies the assumptions used,
- The findings are well aligned to the simulations,
- The payback study is very informative and the analysis makes a powerful case for gasoline, unless the Diesel engine can contain the cost differential.

The reporting of fuel savings is mainly done with respect to each engine baseline. This is reasonable given the unique characteristics of each platform. Nevertheless it would seem necessary to compare each engine platform in the case of the MD and Pickup sector.

8-4. Please provide any other comments you may have on this report.

The discussion on vehicle specifications (Section 4) is limited. The charter indicates the need of a comprehensive “specification sheet” be examined for the MD sector. It may be worth attempting to sketch this, possibly along the lines of the table shown in the commentary of Section 4 above.

Overall Recommendation

9-1. Based upon your review, indicate whether you find the report: (1) acceptable as is, (2) acceptable with minor revisions, (3) acceptable with major revisions, or (4) not acceptable. Please justify your recommendation. If you find the report acceptable with minor or major revisions, be sure to describe the revisions needed.

I find the report acceptable with minor revisions.

The report presents an excellent simulation study throughout a very comprehensive list of combinations for engine and vehicle technologies. It is very informative.

Minor revision requested are:

1. Correct typos as indicated in this charter revision (see earlier sections)

2. Update Conclusions to specify more systematically a breakdown of fuel savings per category, including evaluation regarding the complexity or risk.

3. Clarify how the entries on Table 6.1 and 6.2 were calculated. Given that the comparison approach differs from the earlier section, please show how they are estimated based on the results from Section 2.

COMMENTS SUBMITTED BY

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"Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #3"

Section 1. Introduction

1.1 Does the introduction in Section 1 provide sufficient background on the overall program and the two prior reports in this series to allow this report to be read as a stand-alone document?

- Yes, section 1 provides sufficient background for this report to be read as a stand-alone document

1.2 Does the introduction adequately detail the report contents?

- Yes, the introduction adequately describes the report contents

Section 2. Combined Benefits Simulations

2-1. Please comment on Section 2. The purpose of this section was to explore which technologies provide benefits that are additive, which provide benefits that are not additive, and whether any technologies are synergistic, and to quantify the overall fuel consumption improvement from combining multiple technologies. Please comment on the quality, scope, and rigor of methodology used for the performance analysis of the vehicle and engine technology combinations (packages). Is the methodology clearly described and appropriate to the aims of the project? Is it sufficiently comprehensive and robust to provide credible results?

- The methodology used for this analysis was rigorous and appropriate for the aims of the project. It was also comprehensive enough to provide credible results.
- In general the methodology was clearly described, but there could have been more context provided for why some specific combinations of engine and/or vehicle technology were chosen. In many cases the logic is clear, in others it is not. For example, it is not completely clear why DD15 engine package 3b was chosen for vehicle technology package 4 (T700) or why DD15 engine package 5 was chosen for vehicle technology package 5 (T700) – as opposed to one of the other engine technology packages.
- The charge says that part of the purpose of this project was to evaluate the additive nature and synergistic relationships between different options for fuel economy improvement. To that end the authors did explore combinations of both engine and vehicle improvements for the T700 truck (vehicle technology packages 4 and 5). However, they did not do so for any of the other trucks; for the F650, T270, and Ram Pickup the vehicle technology packages included only the baseline engines – no packages included any of the modeled advanced engine packages. The reason why engine/vehicle synergies were only explored for the T700 and not the other trucks should be explained and justified.

2-2. Were the technologies selected for the combinations appropriate, and were they logical pairings for the engines and vehicles simulated? If not, why not and what would you recommend?

- The technologies selected for the different combinations that were analyzed were appropriate and logical.
- The charge says that part of the purpose of this project was to evaluate the additive nature and synergistic relationships between different options for fuel economy improvement. To that end the authors did explore combinations of both engine and vehicle improvements for the T700 truck (vehicle technology packages 4 and 5). However, they did not do so for any of the other trucks; for the F650, T270, and Ram Pickup the vehicle technology packages included only the baseline engines – no packages included any of the modeled advanced engine packages. The reason why engine/vehicle synergies were only explored for the T700 and not the other trucks should be explained and justified.

2-3. Were the vehicles and drive cycles used in the study appropriate within the context of evaluating Class 2b-8 fuel consumption performance?

- Yes, the vehicles and drive cycles used in this study were appropriate to the task of evaluating Class 2b-8 fuel consumption performance.
- The only way in which the chosen vehicles and drive cycles do not adequately cover the full range of Class 2b-8 vehicles is that they do not address vocational vehicles with significant engine-driven vocational loads – for example refuse trucks (hydraulic packer), cement mixers, utility trucks (aerials), etc. That being said, these vehicles likely represent a very small percentage of total fleet-wide fuel use, so incomplete coverage of these vehicles in this project will not significantly reduce the value of the results.

2-4. Were the computer models chosen appropriate for the analysis, and were they applied correctly to model vehicle and engine technology performance?

- This is not my area of expertise, but given my limited knowledge it appears that the computer models chosen were appropriate to the task and applied correctly. I believe that there is adequate description and discussion of the models, their limitations, and the assumptions used, for informed readers to make appropriate judgements about the accuracy and utility of the results.

2-5. Are the assumptions used in the analysis reasonable? Why or why not?

- Yes, the assumptions used in the analysis are reasonable.

2-6. Are the findings and conclusions adequately supported by the data? Describe any findings or conclusions that are not sufficiently supported. Describe any ways in which this section could be improved, as well as any additional key published data relevant to this review that should be included.

- The findings and conclusions of this section are adequately supported by the data

- This section could be improved in the following ways. These suggestions are primarily designed to improve the readability of the report and to help the reader more easily understand the interconnections and implications of the data presented:
    - In section 2.2, pages 10 – 11, when discussing the different drive cycles used in the analysis, for each drive cycle the authors should indicate the relative amount of engine load imposed by the cycle (low to high). In Table 2.10 the individual drive cycles should be listed in order of low to high engine load from left to right.
    - For all of the tables and figures in Section 2, the results should be consistently shown with the different drive cycles in order of low to high engine load from left to right – i.e. for Figure 2.1 the order from left to right should be WHVC, CARB, 55 MPH, 65 MPH, NESCCAF, rather than the order in the existing figures. This would allow the reader to more easily see the relationship between the fuel economy results and the relative severity (engine load) of the duty cycle, which for many of the technologies appears to be fairly consistent.
    - For all of the tables and figures in Section 2, in addition to results for the individual drive cycles the authors should also show results for a weighted average of the CARB, 55 MPH, and 65 MPH cycles, as currently used in GEM for certification under NHTSA/EPA Phase 1. This would more easily allow the reader to put these results into the context of existing regulations and therefore judge how they might apply to future regulations.
    - In tables 2.2, 2.3, 2.4, and 2.5, for the description of the engine and vehicle technology packages the authors are not consistent in how they number each package, which is confusing. For example, in Table 2.2 which describes engine packages for the ISB medium-duty engine the notes for Package 9 say: “Compare to package 1”, but Package 1 is not an engine package for the ISB medium-duty engine, it is an engine package for the DD15 heavy-duty engine (Table 2.1). For Package 9 the note should say “Compare to Package 6” (the first package for the ISB engine in Table 2.2). There are numerous other similar examples that should be corrected because it is confusing as written.
    - For all tables in this section, every number in a given table should be shown with the same number of significant digits (i.e. if numbers less than 10 are shown with one significant digit (2.0) then numbers greater than 10 should be shown with one significant digit as well (10.0, not 10)
    - In Section 2.3.2.10 there appears to be a mistake. The text says: “The overall fuel savings performance of the P3f system is similar to that of the P3d <u>Ethanol</u> + recuperator system.” I believe that this sentence should say “The overall fuel savings performance of the P3f system is similar to that of P3d <u>Methanol</u>, + recuperator system”.
    - The fact that this section directly compares in the same tables and figures the “Fuel Savings %” for different configurations of diesel and gasoline engines, with Fuel Savings denoted in gallons, is somewhat mis-leading to the reader. The text does note the fact that diesel has 13% more energy per gallon than gasoline, but it is hard for the reader to translate this information so as to compare the gasoline and diesel engine options on an energy equivalent basis. In addition to the existing tables and charts, the report should include figures which directly compare the modeled

gasoline and diesel engine options on an energy-equivalent basis. There are several option for doing this, all of which would be essentially equivalent; one could plot the % reduction in btu/mi or btu/cycle, or one could plot the % reduction in gasoline-gallon equivalents (GGE) per mile or GGE/cycle. Alternatively, one could plot the % reduction in carbon dioxide (CO_2) emissions per mile or per cycle. This option would be appropriate given that this report is in support of joint NHTSA/EPA rulemaking that will set fuel economy and GHG emission standards. At a minimum this information should be added to sections 2.3.5.16, 2.3.7.1, and 2.3.9.17.

- It is hard for the reader to evaluate whether the range of aerodynamic drag and rolling resistance reductions included in the T700 vehicle packages (15%, 25% C_d reduction; 10%, 30% C_{rr} reduction) was reasonable, because there is no discussion in the document of what types of changes might be required to the baseline truck in order to achieve this level of reduction. For example, photos of the Kenworth T700 show that it has a very aerodynamic shape. What changes to the T700 cab and/or standard trailer would be required to reduce the combined C_d by 25%? What specific model of tire was assumed for the baseline T700 and why? Are there commercially available tires for this truck that would reduce C_{rr} by 30% compared to the baseline tire? Providing this information, along with a photo of the baseline truck and trailer that was modeled, would allow the reader to better put the data in this report into the proper context.

Section 3. Vehicle Parameter Sweeps

3-1. Please comment on Section 3. The purpose of the parameter sweeps was to gain an insight into the sensitivity of vehicle fuel consumption to the various parameters considered. Were the parameters chosen for the simulation sweeps realistic for the medium-duty vehicle segment?

- Yes, the parameters chosen for the sweeps represent a realistic and comprehensive range of vehicle characteristics that could affect fuel use for medium-duty vehicles.

3-2. Were the ranges used for each parameter in the sweeps appropriate?

- For aerodynamic drag it is difficult for the reader to evaluate whether the range used in the sweeps was appropriate because there is no discussion in the document of what types of changes might be required to the baseline trucks that were modeled in order to achieve this level of reduction. For example, photos of the Kenworth T270 show that it has a somewhat aerodynamic shape, but not as aerodynamic as the Kenworth T700, for example. Would changes to the T270 cab to make it look like the T700 cab reduce C_d by 10%? What more would be required to reduce C_d by 20% or 30% (i.e. rounded top and corners for box body, roof fairing between top of cab and top of box, side fairing between side of cab and side of box, other?). Photos of the baseline vehicles, and discussions of the types of changes required to achieve 10%, 20%, and 30% reduction in C_d would be very helpful to the reader to put the results of the aerodynamic sweeps into the proper context.

- For rolling resistance it is difficult for the reader to evaluate whether the range used in the sweeps was appropriate because there is no discussion in the document of what types of changes might be required to the baseline trucks that were modeled in order to achieve this level of reduction. For example, what specific model of tire was assumed for the baseline trucks and why? Are there currently commercially available tires for these specific vehicles that would reduce rolling resistance compared to the baseline tire by 10%, 20%, and 30%? Including this type of discussion in the document would be very helpful to the reader to put the results of the rolling resistance sweeps into the proper context.

- The ranges for the weight and axle ratio sweeps are appropriate.

3-3. Were the vehicles and engines used in the parameters sweeps appropriate?

- Yes, the vehicles and engines used in the parameter sweeps were appropriate

3-4. Are the results plausible and well supported?

- Yes, the results of the parameter sweeps are plausible

Section 4. Vocational Truck Fuel Consumption and Performance

4-1. Please comment on Section 4. The purpose of the analysis in this section was to explore the effect of vehicle specifications (explored in Section 3) on vocational truck fuel consumption and performance, as well as to consider the potential for a market shift towards gasoline power in the vocational segment. Are the discussions accurate and relevant to the subject matter?

- Yes.

4-2. Are the assumptions used in the payback discussions appropriate?

- All of the assumptions used in the payback analysis are appropriate except annual miles per truck, which appear to be quite conservative (high). Edition 33 of the Transportation Energy Data Book indicates that in 2012 the average annual miles driven by Class 3 – 8 single unit trucks was 12,816 miles (Table 5.2). It is therefore not clear why the authors chose to use 25,000 miles per year in the payback analysis. The use of a larger assumption for annual miles reduces the payback period for diesel trucks relative to advanced gasoline trucks – as such the author's analysis is quite conservative – for the "average" truck owner the payback periods would in fact be significantly longer than those shown, providing even greater incentive to switch to gasoline medium-duty trucks.

Section 5. Natural Gas Vehicle Cost Survey

5-1. Please comment on Section 5. The purpose of the analysis in this section was to describe a survey of current truck market costs for natural gas engines and natural gas fuel storage systems. Are the initial discussions accurate and appropriate?

- The initial discussions about natural gas engines and natural gas storage systems are appropriate and for the most part accurate – see below for areas that require further elaboration

5-2. Are the natural gas vehicle survey details correct, comprehensive, and sufficiently explained?

- In section 5.1, page 84 it is noted that "if a CNG tank is filled rapidly, usable capacity is reduced by about 20%. Only a slow (typically overnight) fill will get the tank to full capacity". I do not believe that this is an accurate statement. It is typical and acceptable for fast-fill CNG stations to use a temperature compensated fill algorithm to allow up to 4,500 psi in the cylinder at the end of fueling, as long as the "settled pressure" once the gas and cylinder has cooled to 70 degrees F would be no more than 3,600 psi (see, for example http://www.afdc.energy.gov/bulletins/2014_09_18_CNG_Temp.html). With proper temperature compensation even fast-fill stations should be able to fill a tank to greater than 80% rated capacity.

- I believe that section 5.4 (natural gas prices) would benefit from a longer-term historical comparison of natural gas versus diesel price trends. US DOE Clean Cities has been issuing quarterly reports on natural gas and diesel fuel prices at public fuel stations since May 2000 (http://www.afdc.energy.gov/publications/search/keyword/?q=alternative%20fuel%20price%20report) and this data could be used to provide this historical perspective. The salient point that would be gained from this comparison is that prior to 2008 natural gas was generally more expensive than diesel fuel most of the time, but nonetheless prices for both fuels tended to go up and down together. Starting in 2008 natural gas and diesel fuel prices were uncoupled. Since 2008 natural gas has generally been less expensive than diesel fuel, but more importantly diesel prices have been more volatile and natural gas prices have not responded to the same price pressures as diesel. Diesel fuel prices have and continue to respond to global macro-economic and political forces that affect global supply and demand for crude oil, while natural gas prices have and continue to respond to local supply and demand, driven by the continuing glut of U.S. natural gas production from the shale gas revolution in the US. This means that there is much greater uncertainty as to the future relationship between natural gas and diesel prices than there has been in the past, which significantly increases the risk of a decision by a vehicle owner to invest in the purchase of a natural gas vehicle.

- In Sec 5.7.1 the authors note that current natural gas engines have significantly lower thermal efficiency than current diesel engines, which is certainly true. However, in Section 4.1 of the report the authors make the case that the future engine changes modeled for this project could significantly narrow the current gap between diesel and gasoline engines in terms of net efficiency, making gasoline engines more cost-effective than diesel engines, especially for medium-duty vocational trucks. The authors should specifically comment and discuss whether the specific engine technologies modeled here for gasoline engines would also be applicable to future natural gas engines (why or why not) and therefore whether the current thermal efficiency gap between diesel and natural gas engines could be similarly narrowed.

- In section 5.7.2 the report says that "Both fast-fill CNG and LNG vehicles take longer to fill than conventional diesel or gasoline vehicles". Some transit bus fleets (for example MTA New York City Transit) have been able to achieve comparable fill times for diesel and CNG buses using very large fast-fill CNG fuel stations. For a 40-gallon fill (typical of NYC buses) the fill time for diesel and CNG buses varies by less than a minute. To achieve this level of performance a very large and costly fuel station is required, but it is possible.

- In section 5.7.3 when discussing the weight penalty associated with natural gas vehicles the authors state "This weight penalty for natural gas vehicles has a modest negative effect on fuel consumption. Based on the results of the modeling conducted here (weight sweeps) the authors should be able to quantify the range of this fuel economy penalty for different types of natural gas trucks.

- The natural gas vehicle survey does not include any discussion of greenhouse gas (GHG) emissions benefits or dis-benefits of natural gas trucks relative to diesel and gasoline trucks. Given that this report is in support of joint NHTSA/EPA rules to implement combined fuel economy and GHG regulations I believe that the report should include such a discussion. The discussion/analysis should account for net GHG benefits/dis-benefits based on both fuel carbon content and real-world differences in net thermal efficiency for natural gas versus diesel and gasoline trucks. The analysis/discussion should also include upstream emissions of CO2, CH4, and N2O from fuel production and transport, to provide a full wells-to-wheels comparison of natural gas trucks relative to diesel and gasoline trucks.

Section 6. Project Conclusions

6-1. Please comment on Section 6. The purpose of this section was to present project conclusions. Did this section effectively summarize the conclusions of each section of the report?

- Yes, this section did effectively summarize the conclusions of the report with respect to long haul trucks.

6-2. Did this section effectively present overall conclusions?

- The discussion of gasoline versus diesel engine results in sections 6.2 should include a direct discussion of the difference between the modeled gasoline and diesel engines on an energy equivalent basis. Perhaps the easiest way to do this would be to include another table, in addition to tables 6.1, which shows “CO_2 Emissions Penalty on Drive Cycle at 50% Payload”, in addition to the existing data on “Fuel Consumption (gallons) Penalty on Drive Cycles at 50% Payload”

6-3. Are any important conclusions missing or inadequately explained?

- The discussion of gasoline versus diesel engine results in sections 6.3 should include a direct discussion of the difference between the modeled gasoline and diesel engines on an energy equivalent basis. Perhaps the easiest way to do this would be to include another table, in addition to table 6.2, which shows for “CO_2 Emissions Penalty on Drive Cycle at 50% Payload”, in addition to the existing data on “Fuel Consumption (gallons) Penalty on Drive Cycles at 50% Payload”

- In section 6.4, table 6.3 it is not completely clear whether the stated reductions from “engine” and “vehicle” are additive or not. To make this clear the table should include, for each vehicle type, a Total line identifying the range of total fuel reductions possible from both engine and vehicle technologies together. If, for any of the vehicles, the engine and vehicle reductions are not fully additive this should be briefly noted – particularly since one of the purposes of this project was to explore the “additive nature and synergistic relationships between different options for fuel economy improvement”.

  It would also be helpful if this table included the range of percentage reduction in CO_2 emissions available from improved engines for each vehicle type, particularly for those vehicles for which both gasoline and diesel engines were modeled.

Appendices

7-1. Please comment on the four report appendices. Do they provide sufficient technical detail in support of the report sections?

- Yes, the appendixes provide sufficient technical detail

General Comments

8-1. Describe your overall assessment of the organization, readability, and clarity of this report, including any specific recommendations for improvement or changes needed.

- In general this report is well organized, readable, and clear. However the reader's ability to interpret the results and their implications would be enhanced by the following changes:
  - o Reorder the data in all tables and figures in Section 2, so the results are consistently shown with the different drive cycles in order of low to high engine load from left to right
  - o For all tables and figures in Section 2 add one more column which includes results for a weighted average of the CARB, 55 MPH, and 65 MPH cycles, as currently used in GEM for certification under NHTSA/EPA Phase 1.
  - o In sections 2.3.5.16, 2.3.7.1, and 2.3.9.17 add tables, and explanatory text, which directly compare the modeled gasoline and diesel engine options on an energy-equivalent basis (i.e. % reduction in btu/mi or in btu/cycle; or % reduction in gasoline-gallon equivalents (GGE) per mile or GGE/cycle; or % reduction in carbon dioxide (CO2) emissions per mile or per cycle.)
  - o Provide examples of the types of changes that would be required to existing truck models to achieve the different levels of C_d and C_r reduction included in the parameter sweeps.

8-2. Is the information provided in the report and appendices sufficiently detailed to thoroughly document all essential elements of the study? If not, what additional information is needed?

- Yes, information provided in the report and appendices is sufficiently detailed to thoroughly document all essential elements of the study.

8-3. What are the strongest and weakest parts of this report? How can the weakest parts of the report can be strengthened?

- The strongest part of the report is Section 2.
- The weakest part of the report is the Executive Summary - it is too long and complicated. I believe that the report would benefit from a shorter and simpler Executive Summary, more along the lines of the discussion is Section 6, to include: 1) a short back ground on the goals and methodology of the study, 2) a simplified discussion of the types of engine and technology packages simulated (without the very detailed description of each individual engine and technology package), and 3) a high level discussion of the over-all conclusions of the study (without a detailed description of modeling results for each engine and technology package).

8-4. Please provide any other comments you may have on this report.

- None

Overall Recommendation

9-1. Based upon your review, indicate whether you find the report: (1) acceptable as is, (2) acceptable with minor revisions, (3) acceptable with major revisions, or (4) not acceptable. Please justify your recommendation. If you find the report acceptable with minor or major revisions, be sure to describe the revisions needed.

- This report is acceptable with minor revisions. The required revisions are noted above, in particular: 1) re-order data in tables and charts to show drive cycles from low to high engine load from left to right, 2) compare gasoline and diesel engine options directly on an energy-equivalent and/or GHG basis in addition to comparing them on a volumetric fuel basis, 3) use consistent numbering in the description of the engine and vehicle technology packages in tables 2.2, 2.3, 2.4, and 2.5, and 3) shorten and simplify the Executive Summary. These required minor revisions are necessary to enhance the ability of readers to understand the interconnections and implications of the study results.

COMMENTS SUBMITTED BY

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"Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #3"

Section 1. Introduction

1-1. Does the introduction in Section 1 provide sufficient background on the overall program and the two prior reports in this series to allow this report to be read as a stand-alone document?

The report provides a sufficient overview of Report #1 and the overall program. There is no reference to Report #2 that I could find (e.g. searching for '#2' or 'second' yields no hits.)

1-2. Does the introduction adequately detail the report contents?

Yes.

Section 2. Combined Benefits Simulations

2-1. Please comment on Section 2. The purpose of this section was to explore which technologies provide benefits that are additive, which provide benefits that are not additive, and whether any technologies are synergistic, and to quantify the overall fuel consumption improvement from combining multiple technologies. Please comment on the quality, scope, and rigor of methodology used for the performance analysis of the vehicle and engine technology combinations (packages). Is the methodology clearly described and appropriate to the aims of the project? Is it sufficiently comprehensive and robust to provide credible results?

Weight was discussed specifically as a non-additive feature of some of the technologies used. Other than that, there was not a consistent and explicit discussion of if the technologies were additive or not. This could be done if the impact of individual technologies were assumed to be completely additive – one could then compare to the simulated results with the technologies deployed in a single simulation. Technology packages which outperformed the individual summation of technologies are synergistic, technology packages which did about the same are additive, technology packages which were much less interfere with each other. This could possibly be done on a 'meta' level looking at results from this study and that from Report #1.

Assumptions are often made and could be documented better. Once can search for the word 'assume' throughout and find many examples that could be better documented. For instance, source of assumption for "For 2019 baseline diesel engines, an assumption was made that there would be a 1% efficiency improvement due to combustion system development." in 2.1.1 – what is this assumption based on?

The vehicle simulation approach uses well-known simulation packages and is believed to be appropriate for the type of analysis conducted.

Regarding this: "Because WHR systems have very slow transient response, they do not contribute much useful work on highly transient cycles." I agree that the first half of the statement is accurate but not the second. If there is a cycle with a high average heat rejection that is transient a WHR system can still do well. I think this needs to be re-evaluated – assuming that a WHR system produces nothing on certain cycles is because they are 'transient' is not well supported by the report. It may be true, but it is a large assumption that is not backed up.

Regarding the GT-Power simulations, the details of this were presented and peer-reviewed in Report #1. I made a quick review of this but given that this was the subject of the Report #1 and there are little technical details in this report I am not providing specific comments.

The methodology section (2.2) could be enhanced some more with a particular focus on the approach used to validate the engine technologies. Many of the technologies simulated were extrapolations off of existing technology so a robust validation was not possible – that is quite relevant given the purpose of the report. Much of this was covered in Report #1 – but this should be emphasized here to provide good context for the work under review.

2-2. Were the technologies selected for the combinations appropriate, and were they logical pairings for the engines and vehicles simulated? If not, why not and what would you recommend?

The approach used to select the select the combinations is not clear. For instance, why is the “1% combustion efficiency improvement” and “FMEP reduction” not applied to vehicles with the bottoming cycle in the DD15 scenarios? I don’t see why these technologies would necessarily not work together. I realize that one can’t simulate every permutation but it is unclear what process was used. I would recommend clearly defining how these packages were arrived at.

This information could also be communicated more clearly than the tabular form used.

2-3. Were the vehicles and drive cycles used in the study appropriate within the context of evaluating Class 2b-8 fuel consumption performance?

I believe that that vehicles were representative. This could be backed up further with fleet data demonstrating the prevalence of these classes of vehicles in the US fleet.

I believe that the drive cycles were appropriate.

2-4. Were the computer models chosen appropriate for the analysis, and were they applied correctly to model vehicle and engine technology performance?

The vehicle models were appropriate

The engine modeling approach was appropriate and good judgment was used in accommodating for the weaknesses is this type of tool. (See previous comment about enhancing the discussion on validation of models.)

For the WHR system, see earlier comment regarding transient modeling.

2-5. Are the assumptions used in the analysis reasonable? Why or why not?

There were no assumptions that I found to be unreasonable. However, there are many assumptions that are not referenced to any sort of supporting material. For the majority of these assumptions there exist publications that could be easily references to support the assumed value. I think this should be done in this document – otherwise it is unclear to the public that this number is valid.

2-6. Are the findings and conclusions adequately supported by the data? Describe any findings or conclusions that are not sufficiently supported. Describe any ways in which this section could be improved, as well as any additional key published data relevant to this review that should be included.

I feel that the findings are supported by the data. The key to a simulation like this is to have well-vetted input data to the simulation. Most of the input data for this simulation was presented in Report #1. I feel the process used here is straightforward (although very technical and time consuming to execute…) and that the inputs are really what is driving the results.

I feel that this section would benefit from a 'summary of the summaries" so to speak. Right now there is a tremendous number of tables and figures showing data. At the end of the section, it would be powerful to somehow do a weighted average (or just straight average) of the different cycles and provide a few simplified figures. Another suggestion might be reporting on the min/mean/max/std of the technologies deployed to give an idea of how much variation there is. This would also facilitate comparing between the classes of vehicles. It might also be helpful to pull out technology packages that were identical (or similar) across vehicle classes to show how they change across class.

I have no other specific recommendation other than those that were included above.

Section 3. Vehicle Parameter Sweeps

3-1. Please comment on Section 3. The purpose of the parameter sweeps was to gain an insight into the sensitivity of vehicle fuel consumption to the various parameters considered. Were the parameters chosen for the simulation sweeps realistic for the medium-duty vehicle segment?

Yes, this the selection covers the main factors at the vehicle level.

3-2. Were the ranges used for each parameter in the sweeps appropriate?

Yes – however – there should be citations demonstrating that the chosen ranges are span what is believed to be technically achievable over the relevant time period.

3-3. Were the vehicles and engines used in the parameters sweeps appropriate?

Yes.

3-4. Are the results plausible and well supported?

The majority of the simulation results show consistent and the expected trends. There are a few (see Figure 3.18) that are demonstrate some unusual behaviors. The simulations to do this are fairly straightforward, so it should be easy to isolate and describe why the behavior of these cases (e.g. CILCC below) is so strange. Overall there is great detail on the vehicle/engine models – but something like an inappropriate shift schedule could lead to this type of unusual behavior.

It could be that there is a good explanation of these behaviors – but without that being discussed sufficiently it casts some doubt onto the approach.

Section 4. Vocational Truck Fuel Consumption and Performance

4-1. Please comment on Section 4. The purpose of the analysis in this section was to explore the effect of vehicle specifications (explored in Section 3) on vocational truck fuel consumption and performance, as well as to consider the potential for a market shift towards gasoline power in the vocational segment. Are the discussions accurate and relevant to the subject matter?

Overall this section is not as extensively researched or as comprehensive as the previous section. The discussion is relevant but could be more robust and comprehensive.

4-2. Are the assumptions used in the payback discussions appropriate?

The $9000 assumption for the difference between a diesel and gasoline system needs to be documented. A higher-tech gasoline engine comes with some increase in price (boosting, GDI, etc.) GDI engines may also require particulate matter control in this class of vehicle as well – there is talk of this in the light-duty market based on new regulations.

Need basis for 25,000 miles per year traveled assumption – or make this a parameter that is varied.

The time-value of money is neglected in the payback analysis. Taking this into account is simple and should be included.

Payback periods beyond a certain max vehicle life should be labeled 'Never' in Table 4.2. A 30 year payback period is not really relevant.

Results from Table 4.2 would be easier to view as a figure.

Section 5. Natural Gas Vehicle Cost Survey

5-1. Please comment on Section 5. The purpose of the analysis in this section was to describe a survey of current truck market costs for natural gas engines and natural gas fuel storage systems. Are the initial discussions accurate and appropriate?

Yes, this seems to be a solid review of the market with relevant discussions. Note: I do not have deep experience with commercial CNG in the heavy-duty market. Much of this is related to current market trends and offerings.

5-2. Are the natural gas vehicle survey details correct, comprehensive, and sufficiently explained?

I did not find any errors or omissions and felt explanations were good. See note above in 5-1.

Section 6. Project Conclusions

6-1. Please comment on Section 6. The purpose of this section was to present project conclusions. Did this section effectively summarize the conclusions of each section of the report?

The summary does a good job at highlighting Section 2 but does not highlight results from Sections 3, 4, and 5.

6-2. Did this section effectively present overall conclusions?

Yes – with the caveat from 6-1.

6-3. Are any important conclusions missing or inadequately explained?

No – with the caveat from 6-1.

Appendices

7-1. Please comment on the four report appendices. Do they provide sufficient technical detail in support of the report sections?

As described previously, the Appendices provide information on the inputs to the modeling approach – but not much detail on how the technology maps were derived. I think this is OK as that is described in detail in Report #1 which was peer reviewed as well.

General Comments

8-1. Describe your overall assessment of the organization, readability, and clarity of this report, including any specific recommendations for improvement or changes needed.

Section 2 is very, very figure/table dense. To the point that it is very difficult to make high-level conclusions. As stated previously, providing some summary plots of the data that consolidate results into a single figure would be helpful.

8-2. Is the information provided in the report and appendices sufficiently detailed to thoroughly document all essential elements of the study? If not, what additional information is needed?

Yes. See earlier comments.

8-3. What are the strongest and weakest parts of this report? How can the weakest parts of the report can be strengthened?

The weakest part is Section 4 and Section 3. Section 4 is a simple analysis (which is OK) but assumptions are not well documented and it is not a very complete analysis (see comments.) Section 3 could also use additional explanation regarding some of the curves (see comments.)

A lot of work went into Section 2 – this is definitely the most technically strong portion of the report.

8-4. Please provide any other comments you may have on this report.

No additional comments.

Overall Recommendation

9-1. Based upon your review, indicate whether you find the report: (1) acceptable as is, (2) acceptable with minor revisions, (3) acceptable with major revisions, or (4) not acceptable. Please justify your recommendation. If you find the report acceptable with minor or major revisions, be sure to describe the revisions needed.

Acceptable with minor revisions.

The revisions requested would be to better document the assumptions used which are described above. The majority of my comments on this work are in regards to clarity rather than criticism of the technical side of the work.

COMMENTS SUBMITTED BY

Susan Nelson, M.S.
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Peer Review – Draft Report "Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #3"

Susan Nelson
Managing Member, Blue Stripe Scientific, LLC
Greenville, SC
27 May 2015

The following discussion responds to a request by ERG, Inc. to review the assessment of engine and vehicle technologies for potential improvements in fuel economy and greenhouse gas (GHG) reductions performed by the Southwest Research Institute for NHTSA, to assist the agency in formulation of Phase 2 standards for medium- and heavy-duty (MD/HD) trucks. In general, comments will be provided based on my prior experience and studies related to commercial tires and tire rolling resistance on Class 8 trucks. Where it seems appropriate, additional commentary may be added regarding other topics, technologies, and/or methodologies within the limits of my expertise. I hope this review will provide constructive feedback to the study authors, and will help the preparation of a final comprehensive report to support the progress of commercial vehicle freight efficiency.

Section 1. Introduction

1.1 Does the introduction in Section 1 provide sufficient background on the overall program and the *two prior reports in this series to allow this report to be read as a stand-alone document?*

Report #3 can be strengthened as a stand-alone report with the inclusion of the following in Section 1.0:

- A brief paragraph indicating the *principal* objective and authoring organization of each of the three individual reports. For example, the primary topic of the first report is to analyze the potential of medium- and heavy-duty truck engine and vehicle technologies to deliver reductions in fuel consumption during the 2014-2018 Phase 1 timeframe, introducing each technology one-by-one into a baseline engine and vehicle configuration. The second report evaluates costs associated with implementing fuel savings upgrades, including a few associated technologies – such as automatic tire inflation systems - that were not considered in the earlier engine and vehicle performance simulations. Finally, the third report establishes new engine and vehicle baselines for the post-2018 timeframe, and evaluates the potential additional reductions in fuel consumption that could be obtained by grouping together compatible technologies.
- A single table which presents the vehicles selected for analysis, the vehicle applications, the weight class and GVWR represented by each vehicle, the engine type(s) which were studied for each vehicle, and the drive cycles used in simulations of each vehicle to obtain fuel consumption predictions.

1.2 Does the introduction adequately detail the report contents?

The Introduction provides a clear and concise overview of the contents of the report. Other comments on Section 1 are listed below.

- It should be highlighted that Section 2 technologies include a study of hybrid solutions for the pickup truck. Hybrid solutions were not simulated in Report #1.

- The discussion of bottoming cycle and recuperator solutions should be moved to the paragraph describing Section 2, instead of being included in the description of Section 3.
- In addition to predicting the degree of fuel savings that can be obtained through specific combinations of key technologies, Section 1.0 describes an ambition to identify technology combinations that are directly (linearly) additive, those which are additive but which demonstrate non-linear interactions that may not be predictable from simulations of individual technologies, and those which are in opposition. An analysis of technology interactions has not been explicitly presented in the report. Some clarification of how this objective will be accomplished, either by including a report section, or suggesting future research directions, should be provided.

Section 2. Combined Benefits Simulations

2-1. Please comment on Section 2. The purpose of this section was to explore which technologies provide benefits that are additive, which provide benefits that are not additive, and whether any technologies are synergistic, and to quantify the overall fuel consumption improvement from combining multiple technologies. Please comment on the quality, scope, and rigor of methodology used for the performance analysis of the vehicle and engine technology combinations (packages). Is the methodology clearly described and appropriate to the aims of the project? Is it sufficiently comprehensive and robust to provide credible results?

General Comments. The methodology used by the authors, while not necessarily employing the identical modeling tools, is consistent with the work of other excellent published research (Ricardo, 2011; Muster, 2000) in terms of both model selection and application for the analysis of engine and vehicle technologies. The process used in the current report follows the sequence: 1) development of engine simulation model for known production engine; 2) prediction of effects of technology upgrades expected by a future date to establish new engine models to serve as more appropriate baselines; and, 3) insertion of the new engine baseline model(s) into vehicle simulations to predict total fuel consumption across a range of drive cycles. A key feature of this methodology, also commonly used, is that engine function is not adapted for anticipated decreases in levels of road loads. Additional comments are given in Question 2-2, regarding engine downsizing.

Use of a constant to express the tire coefficient of rolling resistance, Crr, is currently a widely accepted practice in vehicle simulations, even though the coefficient has weak dependence on vehicle speed and load in normal operating ranges (Laclair and Truemner, 2005). To be clear, the contribution of tire rolling resistance to *road load* (considered for practical purposes as a retarding force on the vehicle) is a linear function of total vehicle weight including payload under the constant Crr assumption. At some future point it may be of interest to incorporate tire rolling resistance road load as a function of vehicle load, vehicle speed, and tire pressure in simulation studies.

The authors have been thorough in their explanations of engine technologies, providing details of how each technology works, and the techniques for incorporating each technology into the simulations. Speaking as someone who has limited experience in engines and engine technology, I can only add that the simulation treatments are credible, and the level of elaboration of the technologies contributes significantly to the understanding of the results.

Two areas in which the report could be improved for clarity are the definition of engine/vehicle baselines and the treatment of technology interactions. Each area is discussed briefly for the example case of the DD15 diesel engine and T-700 vehicle.

Engine and Vehicle Baselines. References to the DD15 engine models contained in Report #1 and Report #3 include years 2011, 2012, 2013, 2014, 2017 and 2019. It is understood that the 2011 engine refers to the GT-POWER model developed from test cell data on a 2011 production year DD15, and that this serves as the baseline engine used in Report #1 for technology comparisons. The sequence of engine model updates from that point should be described in a single paragraph, including the technologies or strategies that were applied at each update to arrive at the 2019 baseline engine. It is unclear whether 2011 and 2012 refer to the same engine model, and similarly for versions 2013 and 2014, and whether any model other than that from the 2011 production year and the 2019 DD15 projected baseline was used in any simulations.

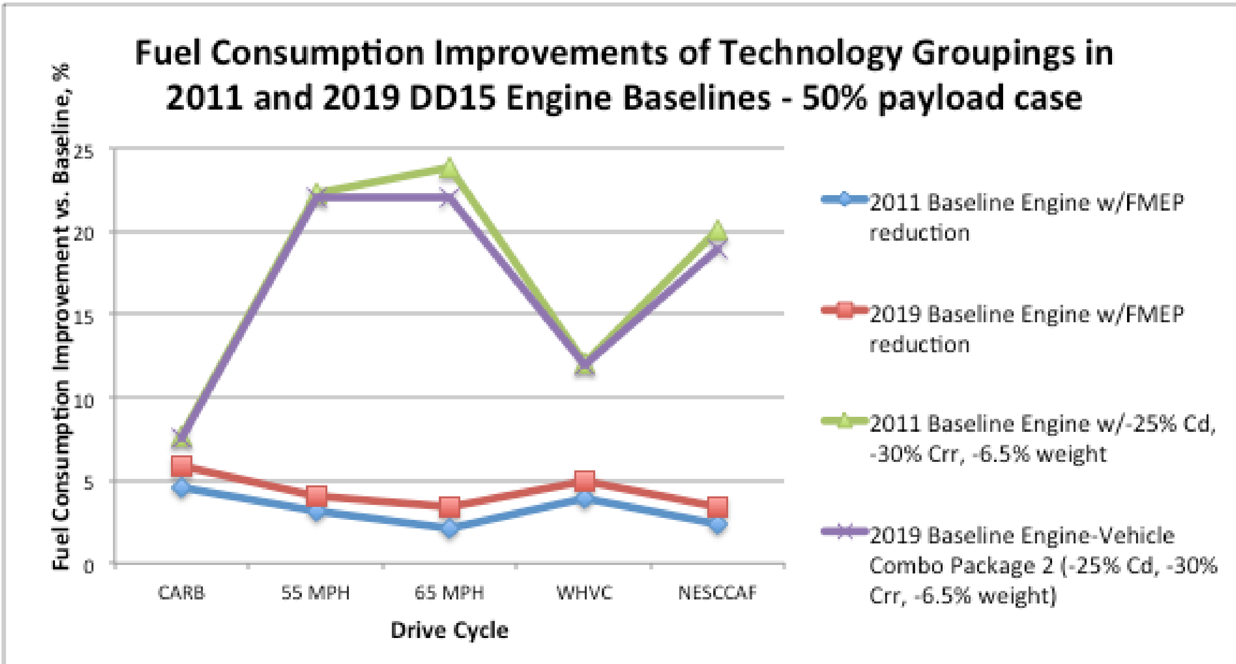
On the vehicle side, it should be clarified there are no differences made to the T-700 vehicle model during the course of the simulations other than replacement of the 2011 engine model with the 2019 baseline engine, e.g. no weight, aero, or tire improvements are assumed for the T-700 in going from the analysis of Report #1 to Report #3.

Interactions of Combined Technologies. Analysis of technology interactions has not been specifically presented in the report. For example, is fuel consumption due to a reduction in Crr affected by different levels of the coefficient of aerodynamic drag, Cd, on a given vehicle? Typically, we would say the answer is no, given the definitions of Crr and Cd embedded in the modeling. One way to explore additive effects on a very macro level would be to compare whether a technology, or package of technologies, provides the same level of fuel consumption improvement when applied to two different baselines.

The following graph shows the percent improvement in fuel consumption due to the same engine friction reduction (FMEP) for both the 2011 and 2019 baseline engines, across all drive cycles. The 2011 baseline DD15 + FMEP improvement (case #11 in Report #1) is compared to the 2011 baseline; likewise, the 2019 baseline DD15 + FMEP improvement (DD15 package #1 in Report #3) is compared to the 2019 baseline engine model.

Similarly, the combined effects of a 25% reduction in Cd, 30% reduction in tire rolling resistance, and 6.5% reduction in empty vehicle weight can be compared by adding the individual contributions to establish an improvement in fuel consumption versus the 2011 baseline (addition of cases II, JJ, and KK-6.5% from Report #1) compared to the T-700 Combined Engine-Vehicle package #2 in Report #3 which combines the same technologies with the 2019 baseline engine model.

These comparisons are shown below for the 50% payload case.



From these results, we would be likely to conclude that these technologies are largely additive, with small differences due to simulation uncertainties, modeling assumptions, or perhaps, real differences in interactions. The friction reduction cases show a consistently greater improvement when applied to the 2019 baseline versus the 2011 baseline engine. Vehicle weight, rolling resistance, and aerodynamic drag are expected to be additive if the baselines are similar enough, as the 2011 and 2019 DD15 models appear to be. More interesting cases could consider combined engine modifications and vehicle technologies, such as substituting the 2019 DD15 engine package 2 (downspeeding + partial FMEP reductions) into the T-700 combo package #2 (25% reduction in Cd, 30% reduction in tire rolling resistance, and 6.5% reduction in empty vehicle weight) to compare with an analogous 2011 package, which may show some evidence of interactions.

2-2. Were the technologies selected for the combinations appropriate, and were they logical pairings for the engines and vehicles simulated? If not, why not and what would you recommend?

General Comments. The current studies have benefitted greatly from well over a decade of continuous and concentrated research into medium- and heavy-duty truck fuel savings technologies summarized by the National Research Council (NRC, 2010 and 2014), the annual merit reviews of the four SuperTruck projects which are reaching the demonstrator phase (Jadin, 2012; Gibble and Amar, 2013; Koeberlein, 2014; Singh, 2014; Rotz and Ziegler, 2014; Delgado and Lutsey, 2014), the 21st Century Truck Partnership (2006), and other research such as an earlier study by MIT (Muster, 2000). Taken together, these programs have provided a generally consistent, progressive and widely reviewed foundation for the selection of fuel savings technologies.

In addition, the level of stakeholder involvement throughout the process is striking, encompassing OEMs and commercial truck equipment suppliers, research labs and universities, regulatory bodies, trucking industry representatives, fleet and maintenance managers, and drivers. Technologies have frequently received significant coverage in end-user literature (Berg, 2014; Brawner, 2015; Lockwood, 2015) and at industry meetings (TMC, 2015), promoting broad dialog in the industry about the advantages/disadvantages, costs, and implementation strategies of new trucking equipment.

Given this context, technology combinations for the T-700 are coherent with approaches reported by other researchers and by the SuperTruck projects, and represent combinations that are pertinent to fuel consumption evaluations.

Technology Selection and Pairings - 6x2 Axle Configuration and Tires. In one study of 6x2 versus 6x4 axle configurations (NACFE, 2014), a 6x2 "package" was identified as containing the following components: wide-base single drive tires on the drive axle, wide-base single trailer tires on the tag axle, "tall" axle ratio of around 2.6:1, use of low viscosity axle lubricant, and direct-drive transmission with down-speeding applied in some cases (approaching T-700 Combo Package 3, excluding aero and accessory power reduction). The NACFE study attributed fuel economy improvements in the range of 1.6% - 4.6% to the use of 6x2 axles, with various adjustments made to account for differences in the make-up of the tested vehicle packages.

A 6x2 axle can permit an overall reduction in tire rolling resistance on the vehicle if trailer tires are used on the tag axle instead of drive tires. An example shown in the following table using SmartWay thresholds for steer, drive and trailer tires indicates a 5% reduction in effective vehicle rolling resistance coefficient by substituting trailer tires on the tag axle, e.g. from a value of Crr(veh) of 5.95 kg/T to 5.63 kg/T. The effective vehicle Crr(veh) is given as:

$$Crr(veh) = [\ \Sigma_j\ Crrj * Zj] \ /\ [\ \Sigma_j\ Zj\ ]$$

where, Crrj is the coefficient of rolling resistance for tires on axle j, and Zj is the total load on that axle. The rolling resistance decrease is considered as an enabled tire contribution to vehicle fuel consumption improvements.

Description	Steer Axle Weight, lb	6x4 Drive Tandem or 6x2 Drive Axle Weight, lb	6x2 Tag Axle Weight, lb	Trailer Tandem Weight, lb
100% Payload case, Total vehicle weight 80000 lb., 6x4				
Load distribution of 46040-lb payload tractor-trailer	**12000**	**34000**	**n/a**	**34000**
% weight carried by axle or tandem	**15%**	**43%**	**n/a**	**43%**
Jan 2015 SmartWay thresholds for Crr tires, kg/T (ISO 25850)	**6.5**	**6.6**	**n/a**	**5.1**
Rolling resistance contribution of axle to Crr(veh), kg/T	**0.98**	**2.81**	**n/a**	**2.17**
Total effective vehicle rolling resistance coefficient, Crr(veh), kg/T	**5.95**			
% Contribution of axle, tandem to total effective vehicle Crr(veh)	**16%**	**47%**	**n/a**	**36%**
100% Payload case, Total vehicle weight 80000 lb., 6x2				
Load distribution of 46040-lb payload tractor-trailer	**12000**	**17000**	**17000**	**34000**
% weight carried by axle or tandem	**15%**	**21%**	**21%**	**43%**
Jan 2015 SmartWay thresholds for Crr tires, kg/T (ISO 25850)	**6.5**	**6.6**	**5.1**	**5.1**
Rolling resistance contribution of axle to Crr(veh), kg/T	**0.98**	**1.40**	**1.08**	**2.17**
Total effective vehicle rolling resistance coefficient, Crr(veh), kg/T	**5.63**			
% Contribution of axle, tandem to total effective vehicle Crr(veh)	**17%**	**25%**	**19%**	**39%**

The NACFE study included some preliminary data indicating that the 6x2 configuration can decrease the wear life of the tires on the drive axle by approximately 1/3, potentially requiring more frequent replacement of tires on this axle. It should be noted that under normal operations trailer tires (on a trailer axle) are likely to have half the wear life of drive tires on a 6x4 configuration (Michelin, 2011). This suggests that trailer tires on the 6x2 tag axle would also need to be replaced more often than drive tires on a 6x4 axle configuration. Effectively, this suggests that tires on both drive and tag 6x2 axles would need to be changed out more often than tires on the drive tandem of a standard 6x4 truck.

This aspect of 6x2 configurations will need to be considered when calculating tire life cycle costs. It should be further noted that heavy-duty truck tires have a non-zero residual value due to the casing which can be retreaded several times. This tire residual value was not reported in the cost analysis of Report #2 (Tetra Tech draft cost study).

Certain new 6x2 products are being developed with the capability to shift load from the tag axle to the drive axle to improve traction. Under this operation, assurance of sufficient tire inflation pressure to support the increased load is critical, as loading can exceed the standard level of 17,000-lb per axle. Wheels must also be able to support the maximum loading.

Aerodynamic Fitments and Tires. Report #3 does not stipulate specific aerodynamic treatments or equipment, but it would not be unusual for a future truck to deploy side skirting which covers both the drive and trailer tandem axles, potentially cutting off convective tire cooling. Airflow around the wheel ends will need to be managed to ensure that tires, wheels, and braking systems are all adequately cooled if isolated from normal ambient airflows.

Engine Downsizing and Reduced Road Load. Engine downsizing is a technology that was not carried over into the combined technologies study. However, combinations of road load reductions can enable engine downspeeding and downsizing in commercial vehicles. This approach has been described in both Daimler and Volvo SuperTruck projects (Delgado and Lutsey, 2014) and has been used in the most recently displayed Daimler SuperTruck demonstrator (McNabb, 2015). An estimated reduction in road load power demand may shift the engine operation to a zone of lower efficiency on the fuel map, which is then compensated for by engine downspeeding and downsizing.

2-3. Were the vehicles and drive cycles used in the study appropriate within the context of evaluating Class 2b-8 fuel consumption performance?

Classes 2b, 6, and 8 commercial vehicles have historically represented the combination of the greatest number of commercial vehicle classes on the road and those which consume the most fuel. Ninety percent of the fuel consumed by all medium- and heavy-duty trucks can be attributed to these classes (NRC, 2014). This characteristic, together with the vehicle selection process described in Report #1, support the decisions to include the Ram pickup, T-270 straight truck, and T-700 Class 8 tractor in the study. Given that data was available to support analysis of the Ford F-650, and that the vocational sector has perhaps been under-represented in fuel consumption studies to date, makes this vehicle a useful addition to the project.

Across all vehicles, including light-duty, tire rolling resistance is estimated to account for 8%-18% of the total fuel energy consumption (engine losses being 50% or greater). The amount of fuel savings due to reductions in rolling resistance can vary as much from vehicle to vehicle as from drive cycle to drive cycle. Estimated sensitivities are reported to range from 10:0.5 to 10:1 in light duty vehicles to 10:1 to 10:3 for medium- to heavy-duty vehicles (Hall and Moreland, 2001). A ratio of 10:3 would be interpreted as a 10% reduction in tire rolling resistance coefficient generating a 3% reduction in fuel consumed, which is a return ratio that approximates Class 8 tractor-trailer sensitivity.

Because of differences in fuel consumed due to rolling resistance for different drive cycles, it is important that each vehicle in the study be subjected to multiple cycles, covering a wide range of operations for a vehicle type. It is unlikely that a single drive cycle can coherently represent vehicle usage. The drive cycles used in the study are familiar and widely used, and, taken as a package for each vehicle type, cover many truck applications. The key decision will be how to combine all or some of the drive cycles to represent the overall usage of each type of vehicle. One approach is to use weighted combinations of fuel consumption from some or all of the cycles studied for a given vehicle category, the values of the various weighting factors being the crucial choice. Alternatively, individual performance targets could be set for each vehicle class for one or more individual drive cycle(s).

2-4. Were the computer models chosen appropriate for the analysis, and were they applied correctly to model vehicle and engine technology performance?

The computer models chosen for engine/vehicle simulations, and the overall modeling approach, are similar to those typically used by other researchers (Laclair and Truemner, 2005; Gibble and Amar, 2013; Ricardo, 2011; Muster, 2000). One notable difference between researchers is whether a driver model is incorporated in drive cycle simulations; an evaluation of this difference is outside my area of expertise.

2-5. Are the assumptions used in the analysis reasonable? Why or why not?

Typical simulation studies assume the tire rolling resistance coefficient, Crr, to be constant across different levels of payload and different speeds, given that the dependence of Crr on load and speed is relatively weak in the normal range of truck operating conditions. Use of a constant coefficient greatly simplifies calculations and sensitivity studies while generally providing satisfactory results.

Tire rolling resistance is a function of load, inflation pressure, speed, applied torque and steer angle, as well as tire temperature, camber, and the wheel used. Moreover, the tire operating temperature, a highly influential parameter for tire pressure, depends on the history of the conditions under which the tire has operated (Laclair, 2005). One approach to determine transient tire rolling losses is to use data from a coastdown machine test to solve for the coefficients in the following equation (Laclair, 2005; Hall and Moreland, 2001):

$$Fr = (P^{\alpha})(Z^{\beta})\,(a + bV + cV^{2})$$

In which:

Fr = tire rolling loss

P = tire internal pressure

Z = vehicle weight carried on the tire

V = speed

a, b, c, α, β = fitted coefficients.

To date the current test method, SAE J2452, has been specified for passenger car and light-truck tires only.

In actual field usage, the tire warms and cools according to operating conditions, altering the internal pressure which in turn dictates actual rolling resistance at any given moment. Predicting tire rolling resistance during the course of a transient drive cycle can be a challenge. On a Class 8 tractor-trailer using steer, drive, and trailer tires, the operating conditions for each tire type are different for each axle. In terms of fuel consumption, a more complex tire rolling resistance model may not offer any improvements in prediction over models based on constant Crr. I am not aware of any studies comparing the use of constant Crr to represent rolling resistance versus the above equation in order to calculate fuel consumption for commercial trucks.

2-6. Are the findings and conclusions adequately supported by the data? Describe any findings or conclusions that are not adequately supported. Describe any ways in which this section could be improved, as well as any additional key published data relevant to this review that should be included.

Technology Interactions. Although occasional comments on the potential additive nature of certain technology groupings are made in the report, this topic has not yet received in-depth treatment. Identification of interactions is one of the primary objectives of the study, and would make a good concluding section for the chapter.

Out-of-Scope Technologies. A brief listing of out-of-scope technologies, such as start-stop, driver habits, active tire pressure controls, continuously variable transmissions, and route optimization can be beneficial for the reader, and also set the stage for future research.

References. The following report discusses differences and similarities between light-duty and heavier pickups and vans, including fuel savings technologies, market and use patterns, and current GHG and fuel consumption standards.

Lutsey, N., “Regulatory Considerations for Advancing Commercial Pickup and Van Efficiency Technology in the United States”, The International Council on Clean Transportation, April 2015, http://www.theicct.org/sites/default/files/publications/ICCT_pickup-van-efficiency_20150417.pdf.

Section 3. Vehicle Parameter Sweeps

3-1. Please comment on Section 3. The purpose of the parameter sweeps was to gain an insight into the sensitivity of vehicle fuel consumption to the various parameters considered. Were the parameters chosen for the simulation sweeps realistic for the medium-duty vehicle segment?

Across the discussions of vehicles, engines, and drive cycles in this section, frequent reference is made to the relative importance of one component of road load versus another on a case-by-case basis. Given that there are generalizations that can be made concerning aerodynamic drag, tire rolling resistance, and vehicle lightweighting, it is recommended that an additional report section be included which presents the classical equations for each of these components. The material could be included at the beginning of Section 3.0 or in an appendix, and would make evident the relationships of:

- Aerodynamic drag force as a function of velocity squared, coefficient of aerodynamic drag, and vehicle cross-sectional area exposed to wind;
- Vehicle inertial forces as a function of vehicle mass and acceleration;
- Tire rolling resistance forces as a function of vehicle mass and the tire coefficient of rolling resistance.

This would make more intuitive the effects of vehicle weight reductions (affecting the road load contributions of both vehicle inertia and tire rolling resistance), drive cycle average speed and speed variability (impacts of aerodynamic drag and inertial effects), and additive improvements due to Cd and Crr (linear relation between the coefficients and road load, and, on the face of it, no interactions between the two coefficients since they do not share any underlying factors in their equations). Fuel consumption sensitivities could be more readily inferred, even for vehicles not subjected to simulation studies, knowing that, for example:

- Fuel consumption of vehicles with greater projected frontal area has greater sensitivity to changes in Cd;
- Fuel consumption of heavier vehicles is more sensitive to changes in Crr;
- Steady-state drive cycles have low sensitivity to lightweighting.

An example of a diagram that can be useful for explaining the relative magnitudes of the road load components during the course of a drive cycle can be found in Figures 29 and 30 of Muster, 2000, illustrated for a highway driving cycle. Similar graphs could be developed for selected cases in Report #3. This visual aide may illustrate more readily and broadly the conclusions of Section 3.1.

3-2. Were the ranges used for each parameter in the sweeps appropriate?

Tire Rolling Resistance Coefficient. Whether the projected reductions in tire rolling resistance coefficient are appropriate depends on what is considered as the baseline Crr value for each vehicle, and whether that value represents a sales-weighted average tire or a best-in-class tire. However, the linear relationship between percent change in Crr versus percent change in fuel consumption can be used to evaluate the impact of potential tire improvements, even if machine measured Crr values are not exactly represented. For pickup trucks, Crr reductions summarized in Lutsey (2015) suggest that 10%-20% reduction is a reasonable working range.

Class 8 tractor-trailers may present more opportunities for rolling resistance reductions than the other study vehicles since the Class 8 vehicle is equipped with several different tire types – steer, drive, and trailer – with each tire type optimized to the operating conditions of its specific axle position. Class 8 enabling technologies, such as the use of 6x2 axle configurations, can permit the vehicle to be fitted with an overall lower Crr tire set. The Ram pickup, F-650, and T-270 use the same tire fitments in all wheel positions, so improvement options are more likely to be limited to direct reductions in Crr.

Aerodynamic Drag/Weight Reductions. Lutsey also reports opportunities for improvements of 10-20% in Cd and also in vehicle weight reductions, based on light-duty simulations. Industry publications indicate Cd ranges of approximately 0.4 – 0.42 for the 2009 model year of this class of pickup truck (Witzenberg, 2009), and Cd ranges of 0.36 – 0.41 for 2015 model years (Sanchez, 2014). The latest Ford F-150 EcoBoost includes a

700-lb weight reduction, or approximately 12-14% of the empty vehicle weight. These values, although not in the same vehicle class, support the range of Cd and weight reduction percentages considered in Report #3.

3.3. Were the vehicles and engines used in the parameters sweeps appropriate?

This combination of vehicles and engines represents an opportunity to compare potential interactions between engine types and each of the three primary road load components. As the weights of the F-650 and T-270 are relatively close in this exercise, it is not surprising that the two vehicles show very similar sensitivities for Crr and lightweighting sweeps.

For the cases presented, there are small differences in engine sensitivity to lightweighting. It would have been interesting to see if more significant differences in sensitivity across the three engine types are observed when paired with Crr reductions.

3-4. Are the results plausible and well supported?

The rolling resistance results for all three vehicles – Ram pickup, F-650, and T-270 - are within the ranges of vehicle sensitivities as a function of weight class discussed in the response to Question 2-3.

Section 4. Vocational Truck Fuel Consumption and Performance

4-1. Please comment on Section 4. The purpose of the analysis in this section was to explore the effect of vehicle specifications (explored in Section 3) on vocational truck fuel consumption and performance, as well as to consider the potential for a market shift towards gasoline power in the vocational segment. Are the discussions accurate and relevant to the subject matter?

Section 4 outlines primary characteristics of vocational vehicle operations that may limit the ability to reduce fuel consumption using lower aerodynamic drag or tire rolling resistance, as well as lightweighting to some degree. This does not mean that these technologies should not be pursued; even moderate improvements can deliver consequential fuel savings. Opportunities for vocational vehicle fuel savings for gasoline and diesel versions have most recently been outlined by Lutsey (2015, Table 3). The majority of these technologies have been addressed in the current report, but there may be others that warrant future consideration.

Vehicle sensitivities can be better compared in graphical summaries similar to Figures 3.7 and 3.8 of the T-700 analysis in Report #1. These graphs report percent fuel savings versus progressive improvements in Cd and Crr, and could be developed for vehicle weight reductions. Including several charts of this type in Report #3, also adding T-700 results from the first report, will show differences in vehicle sensitivities more clearly.

A review of T-270 vehicles offered for sale on the website referenced below confirms that a wide range of axle ratios are actively used in the industry. A quick scan showed used vehicles available with axle ratios of 3.9 – 6.17, with 5.29 being the most common. This reinforces the idea of diversity of usages for vehicles in this category, including considerations for vehicle performance needs of grade capability, acceleration, max speed, and startability as well as fuel consumption, as the authors have briefly described.

http://www.truckpaper.com/list/list.aspx?bcatid=27&Manu=KENWORTH&Mdltxt=T270

4-2. Are the assumptions used in the payback discussion appropriate?

The calculations in Section 4.1 of the report cover the range of probable conditions under which a gasoline engine could compete with a diesel version in the T-270. Payback calculations are based on initial purchase price and the fuel consumed, which are the largest vehicle cost items. Other elements that are typically included in payback calculations, described a recent ATRI summary (Torrey and Murray, 2014) are listed below:

- Repair and maintenance;
- Insurance premiums;
- Permits and licenses;
- Tires;
- Tolls;
- Driver wages and benefits.

All costs associated with the items on this list are likely to remain equivalent for both engine fuel types, with a possible exception in the Repair and Maintenance category, which is not accounted for in the Section 4.1 analysis. The ATRI results indicate that across the survey respondents, which include a range of truck classes and is skewed towards long haul, fuel accounted for $0.645/mile of operational cost in 2013, compared to Repair and Maintenance costs of $0.148/mile. An additional factor for payback calculations is residual value, also not considered here. Data reported for the relatively small sample of straight trucks in the ATRI report indicated 32,901 average annual miles per truck, with an average trade cycle of 9 years.

Assuming no differences in maintenance costs, the analysis in Report #3 depends on:

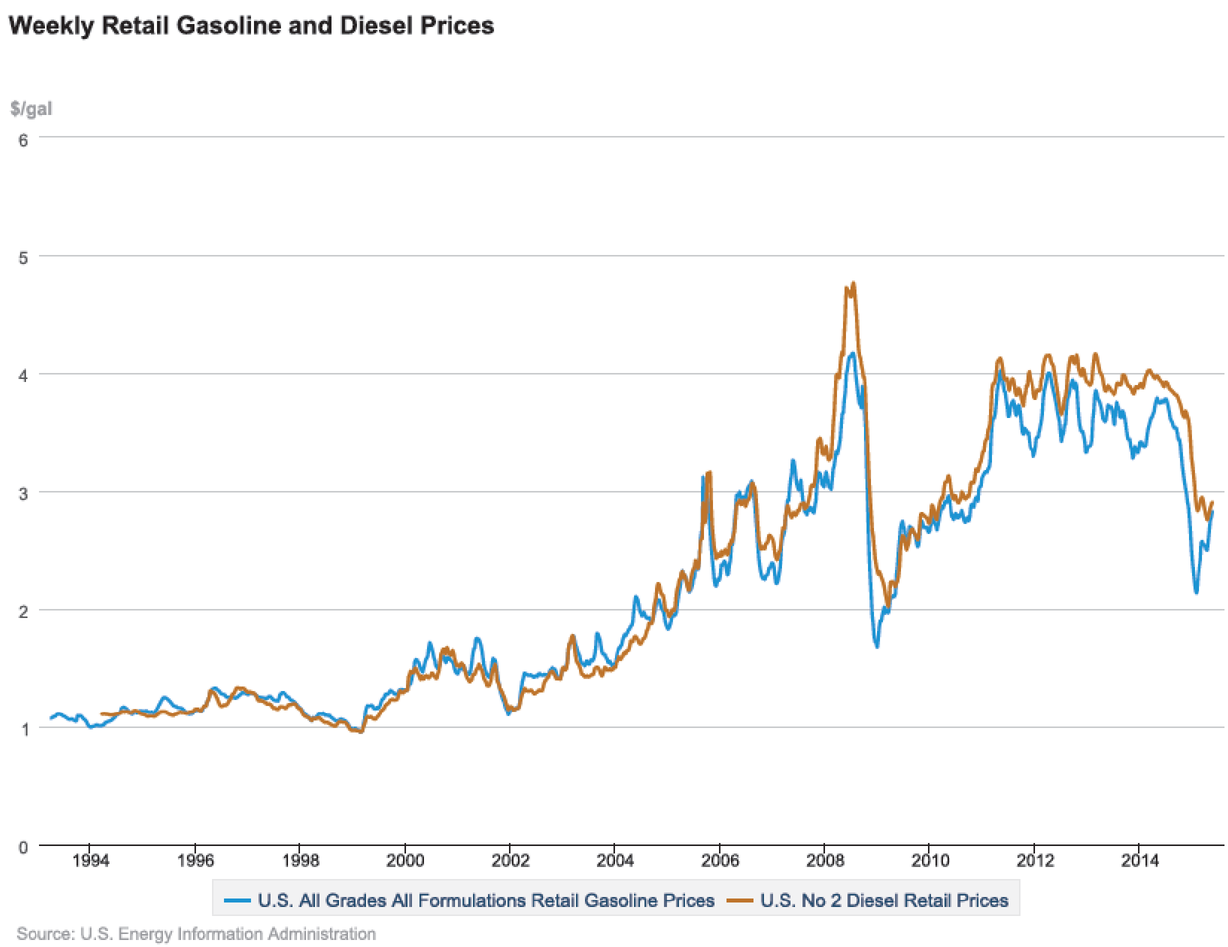
- Difference in vehicle purchase price (V-6 and V-8 both $9000 less expensive than the diesel);
- Differences in fuel consumption between engines;
- Cost of gasoline (taken here as the base);
- Price difference between the cost of gasoline and diesel fuel.

To which we might add,

- Annual mileage;
- Mix and weighting of drive cycle simulations.

Given the variety of applications for this vehicle class, it is difficult to make a case for other than equal weighting of the 6 drive cycles simulated in the study. An increase in assumed annual mileage will make a more favorable case for diesel engines; an annual mileage decrease will favor gasoline engine versions. Including annual mileage as a variable rather than as a constant in the calculations could also be of interest, but it is probably unlikely to significantly change the conclusions of the existing analysis based on 25000 miles annually.

Certainly, the levels and volatility of fuel prices are key to the payback time required to overcome the purchase price differential between gasoline and diesel vehicles. Another version of Figure 4.1 shown in Report #3 comes from the U.S. Department of Energy, Energy Information Administration website (eia.gov), and shows the history of both gasoline and diesel prices in the U.S. (from which Figure 4.1 in Report #3 can be derived). During the period from about 2011 to the end of 2014, volatility of gasoline price has largely driven the differences between the costs of the two fuels, although both fuels experienced significant price drops in the first half of 2015.



Tax differences between the two fuels cannot account for volatility, however, a certain structural price difference is built into current $/gallon values, as shown in the table below, also taken from the eia.gov website. This impact can change based on public policy regarding fuels, governing authority needs for revenue streams, as well as other factors not strictly market related.

Tax entity	Tax on Gasoline, $/gal	Tax on Diesel, $/gal
Federal	0.18	0.24
State – minimum (Alaska)	0.08	0.08
State – maximum (Pennsylvania)	0.516	0.653
Range per gallon of fuel	0.26 – 0.70	0.32 – 0.90

In the end, the future of fuel pricing is difficult to predict, especially in the current period, but we might say that the most likely scenarios would be in the range of $0-$0.25/gal price penalty for diesel. Payback time is extremely sensitive in this range, as seen in Table 4.2 of the report. Given a 9-year average trade cycle and gasoline prices in the range of $3-$4/gal, there are a number of scenarios for which diesel and gasoline engine solutions could be roughly at parity.

Section 5. Natural Gas Vehicle Cost Survey

5-1. Please comment on Section 5. The purpose of the analysis in this section was to describe a survey of current truck market costs for natural gas engines and natural gas fuel storage systems. Are the initial discussions accurate and appropriate?

The information presented in Section 5 aligns with other published analysis of the factors and costs associated with the use of natural gas systems in commercial vehicles. Listings of engine offerings in Report #3 are consistent with earlier summaries presented in Table 7.1 of an ACT whitepaper (ACT, 2012), and cover updates in product offerings since that time. The most commonly mentioned considerations related to the adoption of natural gas vehicles are covered in Section 5.0:

- Vehicle acquisition costs – driven by both engine and on-board fuel storage differences;
- Natural gas versus diesel fuel price differentials;
- Fueling station availability and infrastructure;
- Government incentives;
- Downtime concerns due to natural gas re-fueling times;
- General discussion of maintenance;
- Efficiency differences between diesel and natural gas solutions, including engine efficiencies, weight and aerodynamic effects;
- Impact of wheelbase is a consideration discussed briefly in Section 5.0 that is not often covered elsewhere.

An overview of payback and operational considerations for natural gas vehicles from a fleet perspective is reported by J.B. Hunt (Mounce, 2014). This whitepaper covers purchase price upcharge for natural gas options, observed differences in fuel consumption, vehicle weight comparisons, fuel cost comparisons, as well as presenting two hypothetical scenarios for return on investment calculations, looking at natural gas versus diesel over a 5-year analysis period. Additional maintenance costs were estimated at $0.02-$0.04 per mile for spark-ignited NG engines. Questions of resale, or residual values, of natural gas vehicles are at present unknown. It should be noted that this fleet continues to study the performance and opportunities of natural gas options.

Several elements that can support future ROI analysis, but which are not included in Report #3, are listed below:

- Costs to upgrade existing maintenance facilities plus routine operational maintenance costs for natural gas applications;

- DEF costs for diesel, estimated at around 2-2.5% of fuel costs;
- Comparison of natural gas versus diesel options in terms of risks and potential to meet emissions requirements across the range of GHG and criteria pollutants. A recent article discusses latest estimates of potential methane emissions associated with fleet conversion from diesel to natural gas fuels (Camuzeaux et al., 2015).

5-2. Are the natural gas vehicle survey details correct, comprehensive, and sufficiently explained?

Explanations of the current state of natural gas options and considerations are suitable and properly described. Other details are discussed in the response to Question 5-1.

Section 6. Project Conclusions

6-1. Please comment on Section 6. The purpose of this section was to present project conclusions. Did this section effectively summarize the conclusions of each section of the report?

Section 6 is well written, concise, and clear. Descriptions of potential fuel savings, function and impacts of key technologies and packages, and relevant drive-cycle results are comprehensive without getting lost in details. These are by far the most important conclusions of the study project.

That being said, conclusions from the sections on hybrid solutions, payback calculations for gasoline versus diesel engines in vocational vehicles, and the analysis of natural gas fuel solutions are missing. It is not evident where these items could be inserted into Section 6 without diminishing the impact of the findings contained in this chapter in its current form.

6-2. Did this section effectively present overall conclusions?

Table 6.3 presents the key conclusions in a compact format. However, the approach used to derive the fuel savings percentages in Table 6.3 from the results tables in Section 2 should be explained.

While not at the same level of importance as the results of Table 6.3, conclusions on additive versus non-additive technologies, enabling technologies, and opposing technologies should be addressed if possible.

6-3. Are any important conclusions missing or inadequately explained?

Interpretation of Tables 6.1 and 6.2 can be confusing. A positive percentage means greater fuel consumption (accounting for differences in energy content between the fuel types and the thermal efficiency of the respective engines) of the V-6 or V-8 gasoline engines compared to a projected 2019 diesel baseline. A negative percentage means the gasoline engine consumes less fuel than the diesel, again considering both fuel energy content and engine thermal efficiency. One way to clarify the reading of the tables is to provide a short explanation that walks through one column in each table.

Appendices

7-1. Please comment on the four report appendices. Do they provide sufficient technical detail in support of the report sections?

Vehicles and vehicle technology input data are properly and adequately described in Appendix C for the purposes of the simulations. For clarity concerning the rolling resistance coefficients, it is recommended that the updated discussion of the derivation of Crr values leading up to Table C.9 of Appendix C in Report #1 also be included in Appendix C of Report #3, just before Table C.18.

Some additional clarifications for the Appendices are listed below:

- In Appendix B, Section 1.1 of Report #3, does "original" baseline refer to the 2011 production DD15 for which a test cell dataset was available, or does the term refer to the simulation result of "Technology #7 – Asymmetric Turbo" from Report #1, which was the exercise to model a 2013 DD15? This point should be clarified for both the text and figure titles in this section.
- To reinforce the current study a stand-alone report, it may be beneficial to include the graphs of the drive cycles again in Report #3.
- Aerodynamic drag coefficients Cd w/Trailer of the Dodge Ram and baseline and reduced CdA of the T-700 do not match in comparing Table C.17 of Report #3 with Table C.8 of Report #1.
- Baseline tire rolling resistance coefficient given in Table C.18 of Report #3 for the Dodge Ram does not match the value shown in Table C.9 of Report #1 (as a side note, the Reduced value of Crr reported for the Dodge Ram in Table C.9 of Report #1 should have been 0.005460, and not 0.05460, given the baseline Crr listed in that table).
- Report #3 Sections 2.3.2.4, 2.3.2.5, 2.3.2.6, 2.3.2.7 and 2.3.2.9 refer to Appendix D for discussion of waste heat recovery systems. Section 5.3 also makes reference to Appendix D for information on natural gas vehicle prices. However, Appendix D in the draft of Report #3 is devoted to hybrid systems only.

General Comments

8-1. Describe your overall assessment of the organization, readability, and clarity of this report, including any specific recommendations for improvements or changes needed.

The report is extremely detailed in the descriptions of selected vehicles and their characteristics, the fuel savings technologies, engine technologies in particular, as well as the simulation models used and engine simulation outputs. As in the first report, this can make for some difficult reading. However, since it is infrequent that a study of vehicles, engines, and technologies of this breadth is undertaken, it is felt that the level of detail will in fact be helpful over time, to document as thoroughly as possible the way each technology is understood to work, the assumptions and approximations made in simulations, and how results were interpreted.

The ordering of the main report sections is logical. It is clear how the information in one section is supported by the analysis of the preceding section.

Some comprehension difficulties may arise due to the changing order in which vehicles and engine technologies are presented from section to section. For example, in the Executive Summary a discussion of the DD15 engine and T-700 truck is followed by the discussion of medium-duty and pickup truck gasoline engines, whereas in Section 2 the medium-duty diesel engine discussion comes first. Vehicle technology packages are first described for the F-650 in Section 2, but the first parameter sweeps are presented for the Ram pickup in Section 3. A consistent sequencing of vehicles and engines throughout the report would be very helpful for the reader in keeping the progression of technology packages clear.

As mentioned in the response to Question 2-1, the path taken from the initial 2011 baseline DD15 engine through the sequence of interim model upgrades leading up to the 2019 DD15 baseline should be summarized in one paragraph. Then consistent terminology should be used to refer to the specific baselines throughout the rest of the report.

The process of engine model development is given in Section 2.2, but it is difficult to get a sense of what information is used for model building and calibration, and what is used for model validation. Even though the reader is referred to Appendix A for details, a summary statement describing which charts are used for quality checks during the modeling process reinforces confidence in the approach.

Other recommendations that could aid the reader's comprehension could include (some items mentioned earlier in this review):

- List each DD15 and T-700 technology package in separate paragraphs in the Executive Summary.
- A table of study vehicles, engines, and drives cycles included in the Introduction, as mentioned in the response to Question 1-1.
- Move Section 2.3.9.17, referring to the F-650, to its proper location in the report, or update the section title. (This section currently sits in the middle of the Ram engine discussions.)
- Bring T-700 sweeps results for Cd, Crr, and weight into Report #3, and present the sweeps results for all vehicles in the same format as shown in Figures 3.7 and 3.8 of Report #1.

8-2. Is the information provided in the report and appendices sufficiently detailed to thoroughly document all essential elements of the study? If not, what additional information is needed?

The updated discussion of the derivation of Crr values leading up to Table C.9 of Appendix C in Report #1 should be repeated in Appendix C of Report #3, just before Table C.18.

8-3. What are the strongest and weakest parts of this report? How can the weakest parts of the report be strengthened?

The most impactful parts of the report document the combined engine-vehicle technology package simulation results.

While not particularly weak, the sweeps section of the report could be strengthened by including the standard equations for the components of road load – aerodynamic drag, tire rolling resistance, and vehicle inertial effects due to accelerations (excluding grade for the moment) – then charting the proportion of power demand due to each road load component during the execution of a particular drive cycle. These proportions are frequently referred to in the explanations of the various vehicle sensitivities. The exercise could be accomplished for selected cycles for any vehicle, and would help illustrate the changing proportions of engine power required to overcome each component as the cycle proceeds.

8-4. Please provide any other comments you may have on this report.

The focus of this report is fuel consumption. But as multiple technologies are combined there are greater opportunities for one technology to impinge on non-fuel related performances of another. In the case of tires, the primary functions are to: 1) support the weight of the vehicle and payload; 2) transfer forces between the vehicle and road surface for steering and vehicle control, acceleration, and braking; and 3) isolate payload and vehicle occupants from driving surface roughness or irregularities (Lindenmuth, 2005). Ancillary performances include tread wear life, tire rolling resistance, and durability, the latter being of particular significance for heavy duty truck tires in order to support retreading. Fuel savings systems that may combine to increase mechanical or thermal stresses on tires, or any other vehicle component for that matter, will require careful integration to ensure that the final vehicle solutions continue to deliver the expected suite of performances at the component level.

Overall Recommendation

9-1. Based upon your review, indicate whether you find the report: (1) acceptable as is, (2) acceptable with minor revisions, (3) acceptable with major revisions, or (4) not acceptable. Please justify your recommendation. If you find the report acceptable with minor or major revisions, be sure to describe the revisions needed.

I would recommend the report be published with (a) minor revisions to improve readability and for minor corrections, specifically addressing clarification of the DD15 baselines, the bullet points outlined in the response to Question 8-1, and the updates to the appendices described in the responses to Questions 7-1 and 8-2.

The technology reports within the scope of this project provide thorough, comprehensive analysis of the opportunities for fuel savings in the commercial truck sector, and should serve as valuable references for both rulemaking and for future research.

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PEER REVIEW CHARGE

DTNH22-13-D-00298 – Task Order 0003, Report 3

"Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #3"

1. Introduction

1.1 Does the introduction in Section 1 provide sufficient background on the overall program and the two prior reports in this series to allow this report to be read as a stand-alone document?

The introduction provides sufficient background on the overall program.

1.2 Does the introduction adequately detail the report contents?

The hybrid technologies, from Section 2, were not introduced. All other sections were introduced adequately.

2. Combined Benefits Simulations

2-1. Please comment on Section 2. The purpose of this section was to explore which technologies provide benefits that are additive, which provide benefits that are not additive, and whether any technologies are synergistic, and to quantify the overall fuel consumption improvement from combining multiple technologies. Please comment on the quality, scope, and rigor of methodology used for the performance analysis of the vehicle and engine technology combinations (packages). Is the methodology clearly described and appropriate to the aims of the project? Is it sufficiently comprehensive and robust to provide credible results?

The quality, scope, and rigor were definitely there. The models were extensively calibrated with experimental data when available. Many combinations of engine and vehicle technologies were evaluated. The technologies chosen seem to be primarily additive and synergistic. What technologies were not additive? I believe this was explored by the author, but not included or discussed in the document.

The model was sufficiently described and is robust. The results will be best case scenarios since the methodology does not take into account transient effects, road grade, and different ambient conditions. These specific conditions are very important, but seem to be outside the scope of this project.

2-2. Were the technologies selected for the combinations appropriate, and were they logical pairings for the engines and vehicles simulated? If not, why not and what would you recommend?

The technologies selected were logical combinations and pairings.

2-3. Were the vehicles and drive cycles used in the study appropriate within the context of evaluating Class 2b-8 fuel consumption performance?

The vehicles and drive cycles used were appropriate to get a wide breadth of fuel consumption performance. The vocational worksite trucks drive cycles are still the hardest to quantify. The difficulty of quantifying overall fuel consumption reductions for this vehicle type was addressed through discussion.

2-4. Were the computer models chosen appropriate for the analysis, and were they applied correctly to model vehicle and engine technology performance?

The computer models chosen were appropriate for the analysis. GT-Power is an industry accepted and widely utilized software. The background and validation of the in-house vehicle modeling tool developed by Southwest Research Institute (SwRI) was included in Report #1.

2-5. Are the assumptions used in the analysis reasonable? Why or why not?

There were many assumptions applied during the study and they seem reasonable.

2-6. Are the findings and conclusions adequately supported by the data? Describe any findings or conclusions that are not sufficiently supported. Describe any ways in which this section could be improved, as well as any additional key published data relevant to this review that should be included.

The findings and conclusions are supported.

The hybrid system results were not discussed and the table wasn't referenced. The text in the hybrid section did not flow with the rest of the document. The table was organized differently and had different significant figures than the rest of the document. This section needs to be cleaned up.

3. Vehicle Parameter Sweeps

3-1. Please comment on Section 3. The purpose of the parameter sweeps was to gain an insight into the sensitivity of vehicle fuel consumption to the various parameters considered. Were the parameters chosen for the simulation sweeps realistic for the medium-duty vehicle segment?

The parameters of drag coefficient, rolling resistance, vehicle empty weight, and axle ratio were realistic. Why was this only done for the medium-duty vehicle segment? The results from the KW T700 were not shown, but the parameters were included in the appendix.

3-2. Were the ranges used for each parameter in the sweeps appropriate?

The ranges were appropriate.

3-3. Were the vehicles and engines used in the parameters sweeps appropriate?

The vehicles and engines used were appropriate.

3-4. Are the results plausible and well supported?

The results are plausible.

4. Vocational Truck Fuel Consumption and Performance

4-1. Please comment on Section 4. The purpose of the analysis in this section was to explore the effect of vehicle specifications (explored in Section 3) on vocational truck fuel consumption and performance, as well as to consider the potential for a market shift towards gasoline power in the vocational segment. Are the discussions accurate and relevant to the subject matter?

The section on the potential market shift for gasoline versus diesel engines was very interesting and thorough.

4-2. Are the assumptions used in the payback discussions appropriate?

Within my area of expertise, which does not include market costs, the discussions are accurate and appropriate.

5. Natural Gas Vehicle Cost Survey

5-1. Please comment on Section 5. The purpose of the analysis in this section was to describe a survey of current truck market costs for natural gas engines and natural gas fuel storage systems. Are the initial discussions accurate and appropriate?

Within my area of expertise, which does not include market costs, the discussions are accurate and appropriate.

5-2. Are the natural gas vehicle survey details correct, comprehensive, and sufficiently explained?

Within my area of expertise, which does not include market costs, the details are accurate and comprehensive, and sufficiently explained.

6. Project Conclusions

6-1. Please comment on Section 6. The purpose of this section was to present project conclusions. Did this section effectively summarize the conclusions of each section of the report?

The natural gas and hybrid technology results are not discussed in the conclusions.

6-2. Did this section effectively present overall conclusions?

This section presented the overall conclusions.

6-3. Are any important conclusions missing or inadequately explained?

The executive summary and the conclusions section did not reemphasize the limitations and/or accuracy of the model and the reported percent fuel reductions.

7. Appendices

7-1. Please comment on the four report appendices. Do they provide sufficient technical detail in support of the report sections?

The appendices show sufficient technical details. Enough details are shown that similar fuel consumptions results could be reproduced.

8. General Comments

8-1. Describe your overall assessment of the organization, readability, and clarity of this report, including any changes needed.

Overall, the report was organized, readable, and clear with only minor corrections needed. See other sections for the changes needed.

8-2. Is the information provided in the report and appendices sufficiently detailed to thoroughly document all essential elements of the study? If not, what additional information is needed?

The hybrid technology section needs a more complete and thorough discussion.

8-3. What are the strongest and weakest parts of this report? How can the weakest parts of the report can be strengthened?

The wide breadth of combined vehicle and engine technologies analyzed on many different drive cycles was the strongest part of the report.

The weakest part of the report was technologies that were not synergistic or not additive were not discussed. In addition, the hybrid technology section was weak. The discussion was incomplete and did not flow with the rest of the report.

8-4. Please provide any other comments you may have on this report.

Some minor comments and corrections:

Throughout the document:

- replace the term “RPM” with “engine speed”
- Combine one sentence paragraphs with other paragraphs
- Replace “&” with “and”
- Change “max” to “maximum” and ‘min” to “minimum”
- Replace just “speed” with the more specific “vehicle speed”
- Figure title spacing is inconsistent.

In the executive summary:

Please clean up the short paragraphs and lists without bullet points.

“1% combustion efficiency improvement” should be “1% thermal efficiency improvement.”

Introduction:

Page 7. Table 2.8 and 2.9 references to “P2” and “P3” was this supposed to be “P12” and “P13”? Please check all the package references.

Page 9, first paragraph “pluses” should be “pulses”

Section 2:

In the tables of engine technology combinations, the term “1% efficiency improvement” is misleading. Please change to “1% thermal efficiency” improvement.

Page 28. F-650 is mentioned as having “vehicle packages 2 through 5.” From Table 2.8, the F-650 does not have vehicle packages in this number range.

Page 29. Table 2.14 also shows these incorrect package references.

Page 33. “sees a 3% to 4% with the automatic” should be “sees a 3% to 4% benefit with the automatic”.

Page 44. Table 2.20 has two “2019 ISB” rows.

Page 46. The last paragraph should not be centered.

Page 48. Section 2.3.9.10 has a reference to “Package 1” which is incorrect.

Page 51. “Ram vehicle packages 2 through 5.” The Ram does not have vehicle packages in the range of 2 through 5.

Page 55. Figure title at the top of the page.

Section 4:

Define “VMT” in the abbreviations section.

Appendices:

Page 122. Inconsistent spacing.

Page 144. Make a complete paragraph for the figure lists.

9. Overall Recommendation

9-1. Based upon your review, indicate whether you find the report: (1) acceptable as is, (2) acceptable with minor revisions, (3) acceptable with major revisions, or (4) not acceptable. Please justify your recommendation. If you find the report acceptable with minor or major revisions, be sure to describe the revisions needed.

Acceptable with minor revisions. Please see other sections for my revisions.